5th International ASTROD Symposium, July 11-13, Bangalore

INDIAN PAYLOAD CAPABILITIES FOR SPACE MISSIONS

A.S. Kiran Kumar
Director
Space Applications Centre
Ahmedabad

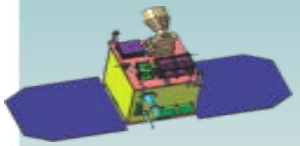
Application-specific EO payloads

(Operational)

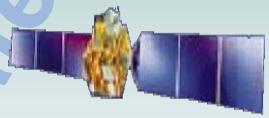
Land & Water

Cartography

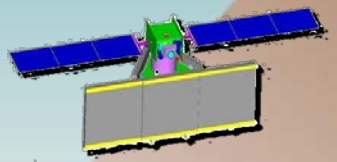
Atmosphere & Ocean



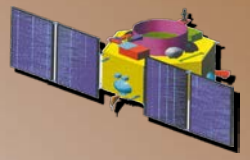
IMS-1(2008)
MX/ HySI-T



RESOURCESAT-2
(2011)
LISS 3/ LISS 4/AWiFS



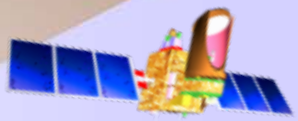
RISAT-1 (2012)
C-band SAR



CARTOSAT-2/2A/2B
(2007/2009/2010)
PAN

RESOURCESAT-1
(2003)
LISS 3/ LISS 4
AWiFS

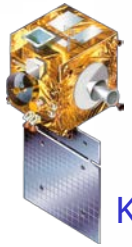
CARTOSAT-1 (2005)
STEREOPAN



Megha-Tropiques
(2011)
MADRAS/SAPHIR/ScARaB/
ROSA

TES(2001)
Step& Stare
PAN

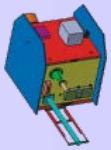
OCEANSAT-2
(2009)
OCM/ SCAT/ROSA



KALPANA-1 (2002)
VHRR

INSAT-3A (2003)
VHRR, CCD

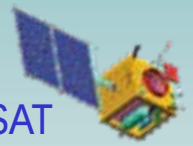
YOUTHSAT(2011)
LiV HySI/RaBIT



Application-specific EO payloads

(Planned)

Land & Water

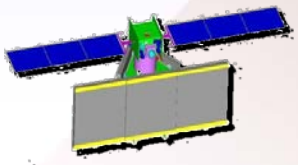


GISAT
MXVNIR/SWIR/TIR/HySI

RESOURCESAT-3A/3B/3C
LISS 3/LISS 4/AWiFS

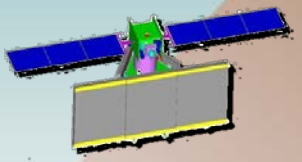
RESOURCESAT-2A
LISS3/LISS4/AWiFS

RESOURCESAT-3
LISS 3/LISS 4/
AWiFS



RISAT-1R
C-band SAR

Cartography

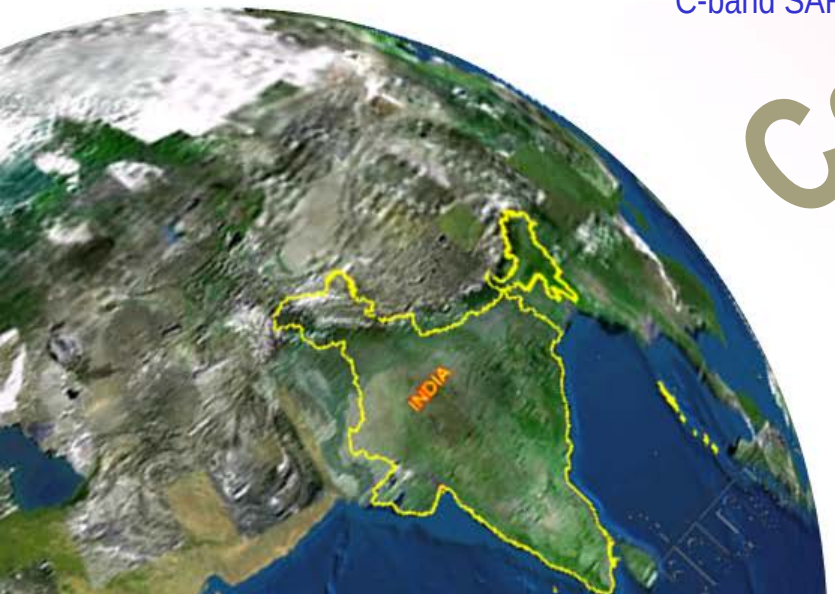


RISAT-3
L-band SAR

CARTOSAT-3
PAN

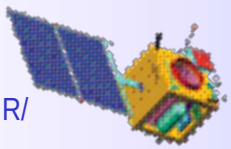
CARTOSAT-2C/2D
PAN

SARAL
Altimeter/ARGOS



Atmosphere & Ocean

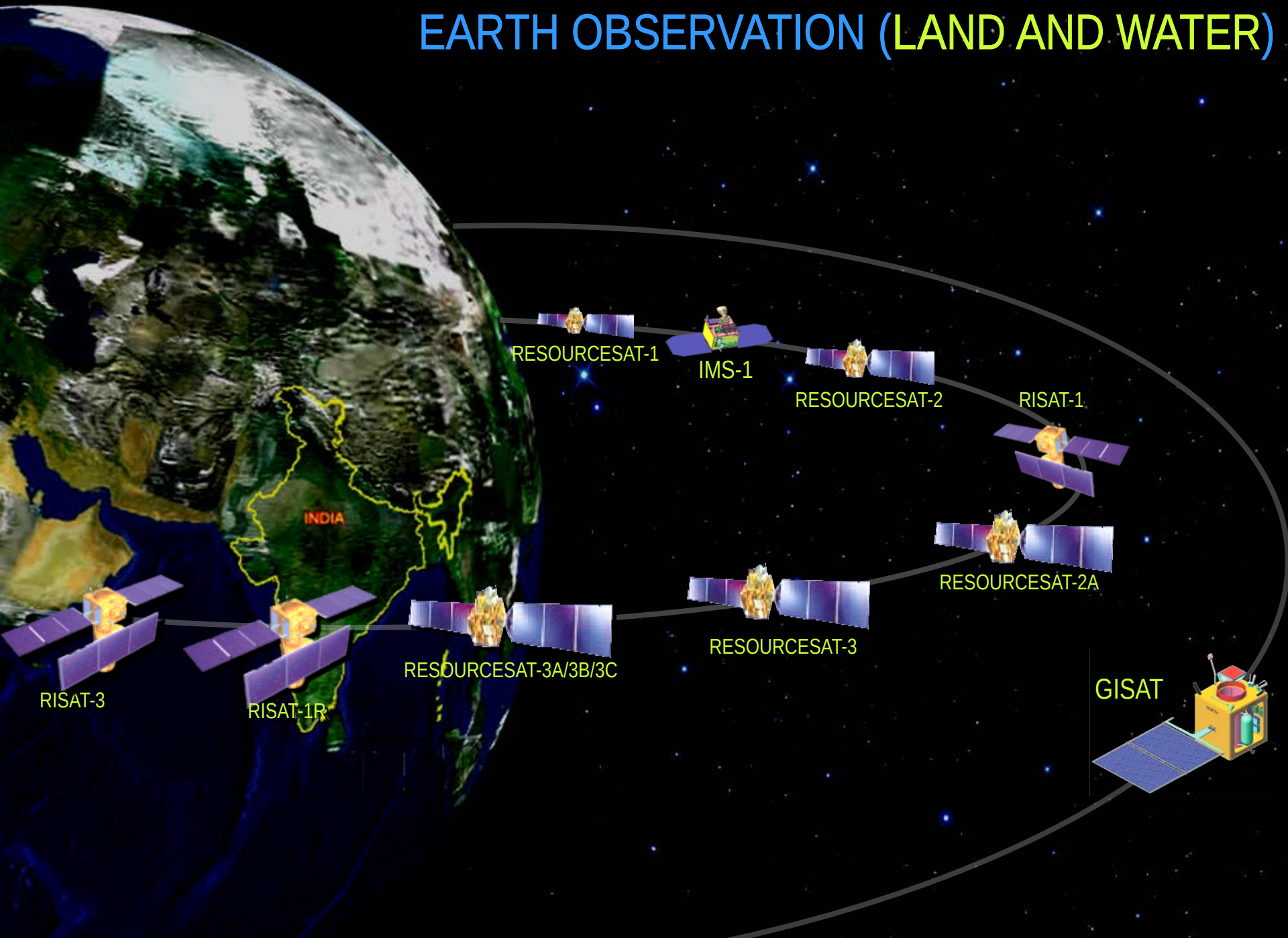
OCEANSAT-3
OCM , TIR



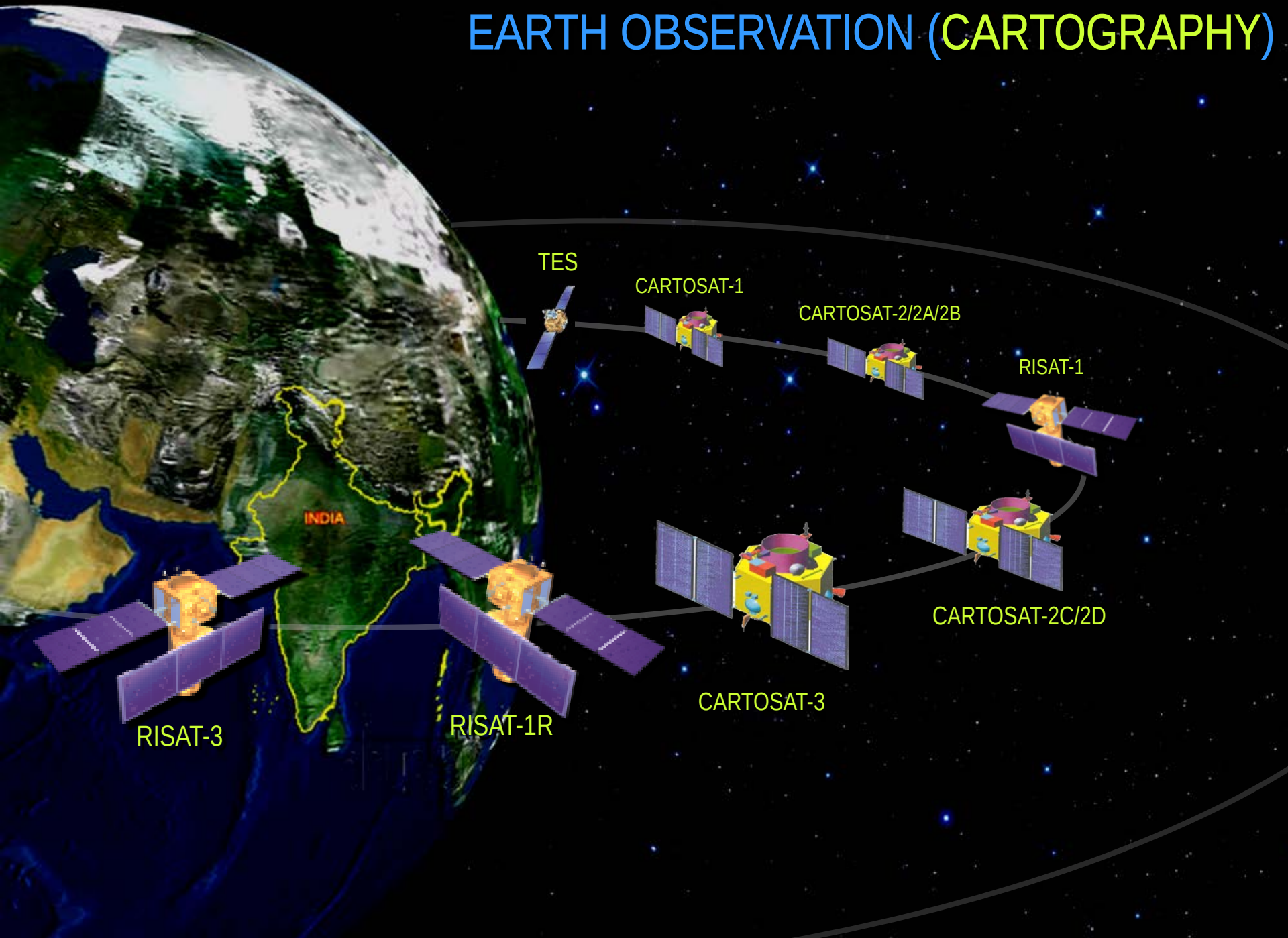
GISAT
MXVNIR/SWIR/
TIR/HySI

INSAT- 3D
Imager/Sounder

EARTH OBSERVATION (LAND AND WATER)



EARTH OBSERVATION (CARTOGRAPHY)



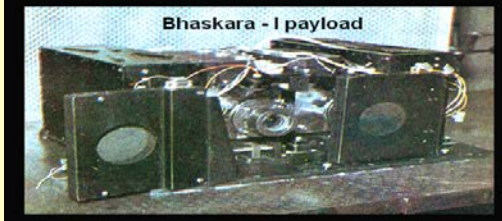
EARTH OBSERVATION (ATMOSPHERE & OCEAN)

Bhaskara (I and II) series

The Bhaskara (I and II) - experimental satellites (1979/1981)

Slow Scan Vidicon camera (operating in 0.54-0.66 micron and 0.75-0.85 micron spectral channels), produced images for land use, snow cover, coastal processes, and for forestry purposes)

Passive Microwave Radiometers (operating in the 19, 22, and 31 GHz range) collected data on sea surface phenomena, water vapor and liquid water content).



The `IRS Series' -

1988-1997 First Generation

IRS 1A/1B

LISS-I/LISS-II

72/36 meter spatial resolution

4 Spectral bands

22 day repetivity

1995-2007 Second Generation

IRS 1C/1D

WiFS 188 meter - 2 band

5 day repetivity

LISS-III 23.5 meter - 3 band VNIR

70 meter SWIR

24 day repetivity

LISS-IV 5.8 meter PAN

5 day revisit

2003-2012 Third Generation

RESOURCESAT 1-2 series

AWiFS 56 meter, 4 band

5 day repetivity

LISS-III 23.5 meter, 4 band

24 day repetivity

LISS-IV 5.8 meter, 3 band

5 day revisit

Current observation capabilities : Optical

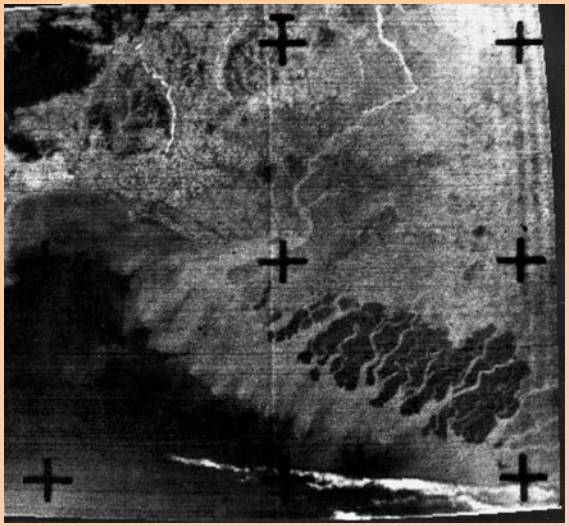
Payload	Sensors in operation	Spatial Res.	Swath/ Coverage (km)	Radiometry	Spectral bands	Repetivity/ revisit
CCD	1	1 Km	India & surround.	10 bits	3 (B3, B4, B5)	4 times/ day
VHRR	2	2 km VIS 8 km WV/IR	Earth Disc	10 bits	3	Every ½ hrs
HySI/ IMS	1	500 m	128	12 bits	64	24 days
OCM-2	1	360m	1420	12 bits	8	2 days
AWiFS	2	56 m	740	10/12 bits	4(B2,B3, B4, B5)	5 / 2.5 days
MX/ IMS	1	37 m	148	10 bits	4(B1, B2,B3, B4)	24 days
LISS3	2	23 m	140	7/10 bits	4(B2,B3, B4, B5)	24/12 days
LISS4	2	5.8 m	23/70	7/10 bits	3(B2,B3, B4)	40/ 5 days
PAN (stereo)	1	2.5 m	30	10 bits	1	100 days
PAN (mono)	4	0.8/ 1 m	10 / 16	10 bits	1	5 day revisit

Current observation capabilities : Microwave

Payload	Spatial Res.	Swath km	Radiometry	Frequency	Repetivity/revisit
Scatterometer	50 Km	1400	10 bits	Ku band	2 days
SAR-X	1m to 8m	10 to 120	10 bits	X	2days
SAR-C	1m to 50m	10 to 220	10 bits	C	25/7days

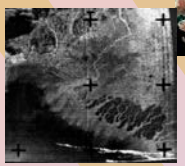
Payload	Spatial Res.	Swath	Frequency bands	Repetivity/revisit
MADRAS	6km to 40 km	1700	5 (18.7 to 157GHz)	Multiple observations per day
SAPHIR	10 km	1700	6 @183 GHz	
ScARaB	40 km	2240	4	
ROSA			L1,L2	~600 occultaions per day

Indian Imaging Capabilities - from Kilometer to sub-Meter



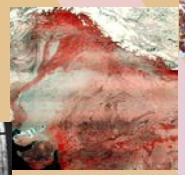
1 Km

BHASKARA TV PAYLOAD



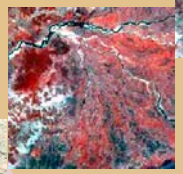
1 Km

BHASKARA TV PAYLOAD



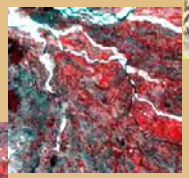
1km

INSAT-CCD



360m

OCM



188m

WiFS

73m

LISS-1

56m

AWiFS

36m

LISS-2

23m

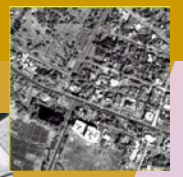
LISS-3

5.8m

LISS-4

2.5m

PAN CARTO-1



< 1m

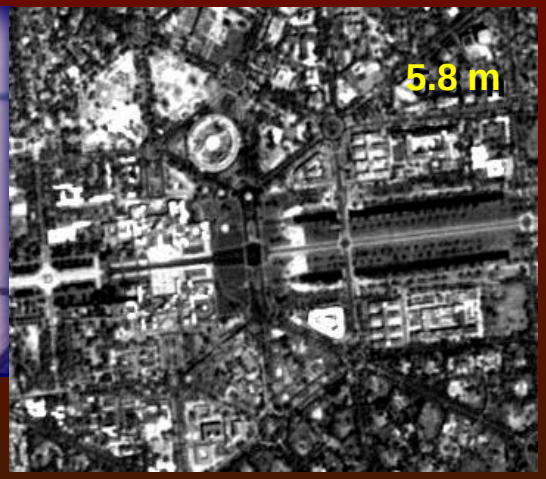
PAN CARTO-2

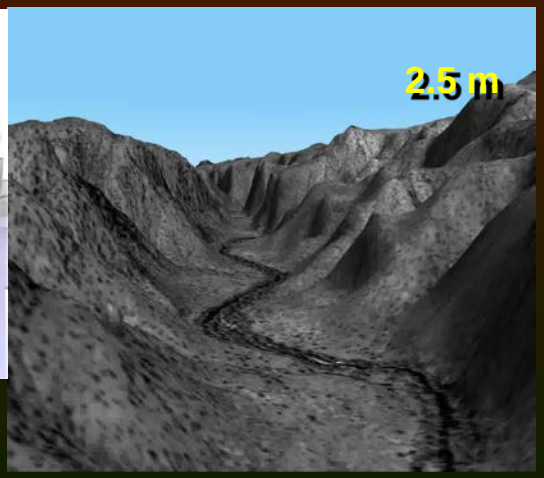
< 1m

CARTOSAT-2 PAN

Imaging Sensor for Earth Observation

Cartographic applications



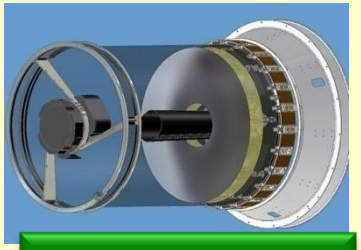


CARTOSAT-2C/2D

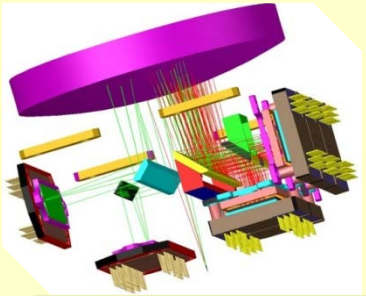
ORBIT	500km POLAR SSO
PAYLOADS	HIGH-RESOLUTION PANCHROMATIC (PAN) HIGH-RESOLUTION MULTI-SPECTRAL (MX)

PAN PAYLOAD FEATURES	
Spectral bands	PAN: 0.45-0.9 μm
Resolution	0.64m
Swath	10Km
Quantization	11 bits
SWR	>10%
SNR	>180

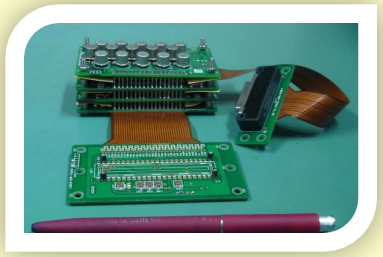
MX PAYLOAD FEATURES	
Spectral bands	VIS1: 0.45-0.52 μm
	VIS2: 0.52-0.59 μm
	VIS3 : 0.62-0.68 μm
	VIS4 : 0.77-0.86 μm
Resolution	1.6m
Swath	10Km
Quantization	11 bits
SWR	>20%
SNR	>500



TELESCOPE



FOCAL PLANE



CAMERA ELECTRONICS

- Compact focal plane providing continuous imaging line (16000 pixels)
- Time-delay-and-integration (TDI) CCD based detection system

CARTOSAT-3 series

Cartosat-3 series (3, 3A, 3B)

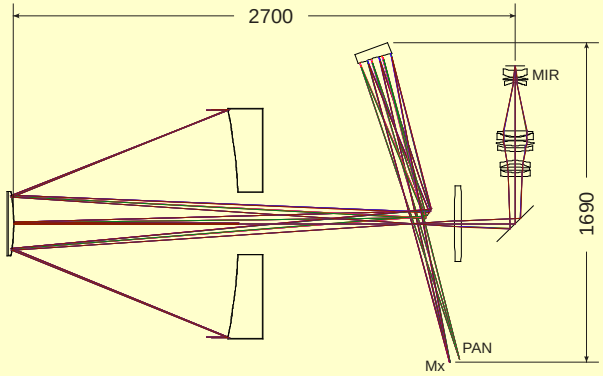
0.25m GSD PAN , 1m Mx and~5m MWIR

16km swath

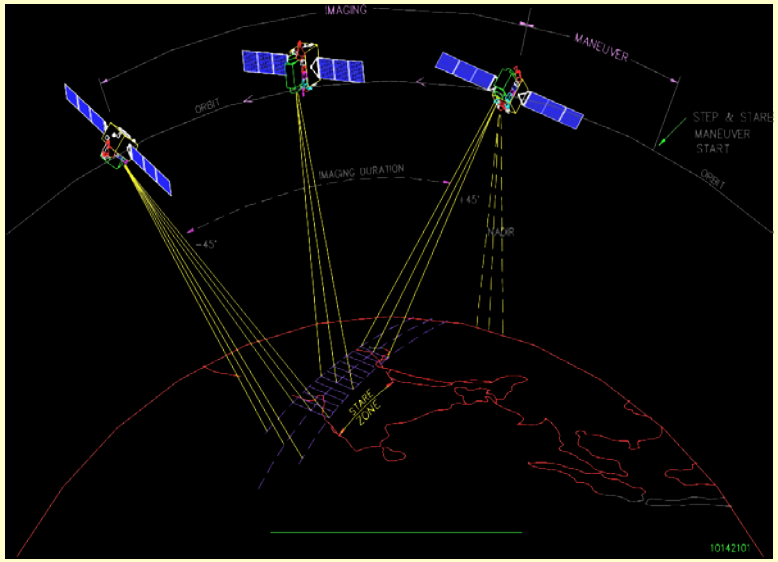
TDI CCD based imager

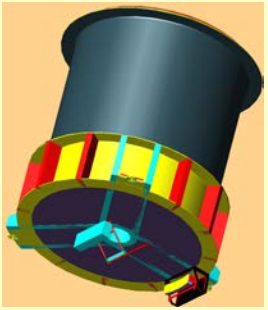
Can provide 64000 Square kilometer data per orbit

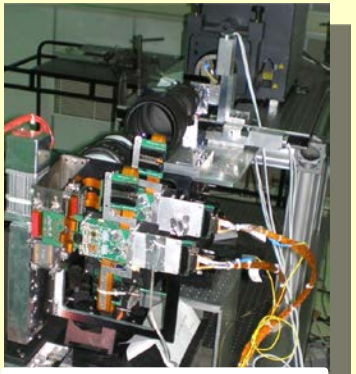
6400 sq km imaging per orbit



0.25 m GSD PAN
0.5 m, 4 band MX
5 m MIR or 30m VNIR+ SWIR HySI
CONTINUOUS IMAGING

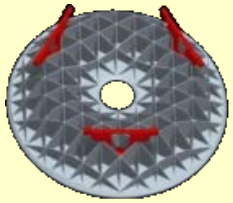




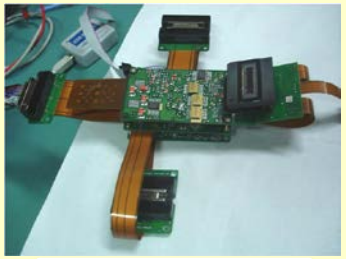


Optical Butting Test bench

HexaPod



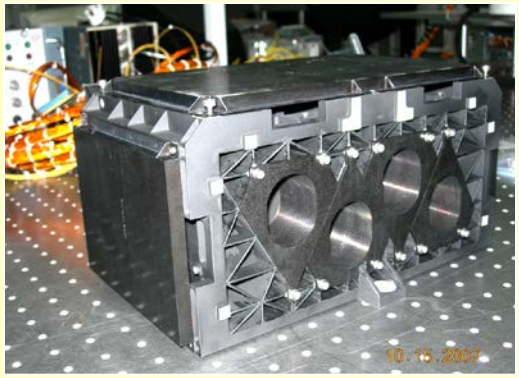
Mirror light-weighted 420 to 70 kg



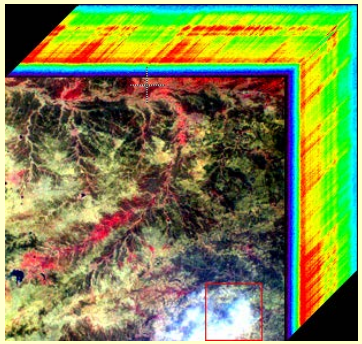
High speed FECE

Indian Mini-Satellite

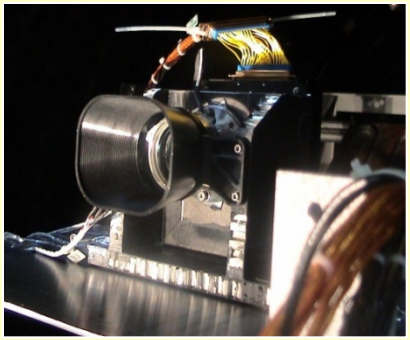
4 Band, 36m GSD with a swath of ~ 140 Km Mx-Imager



HySI Image Cube
Jalgaon Area, 03-Jun-2008

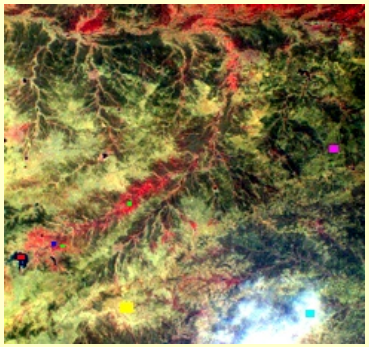


64 bands; 400-950 nm range; Spectral separation 8 nm; Spatial Res. 500 m; Swath 129.5 km

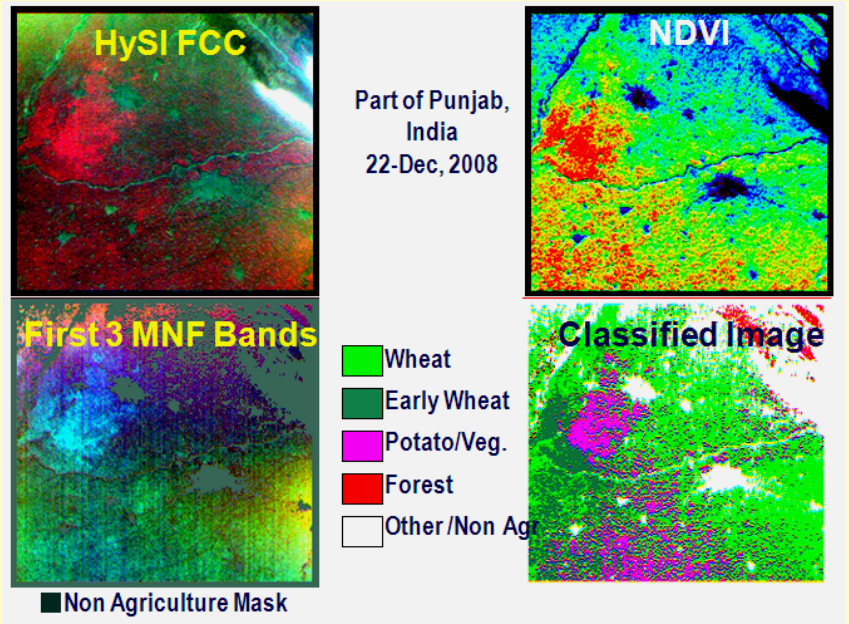


HySI Payload

FCC with Classes

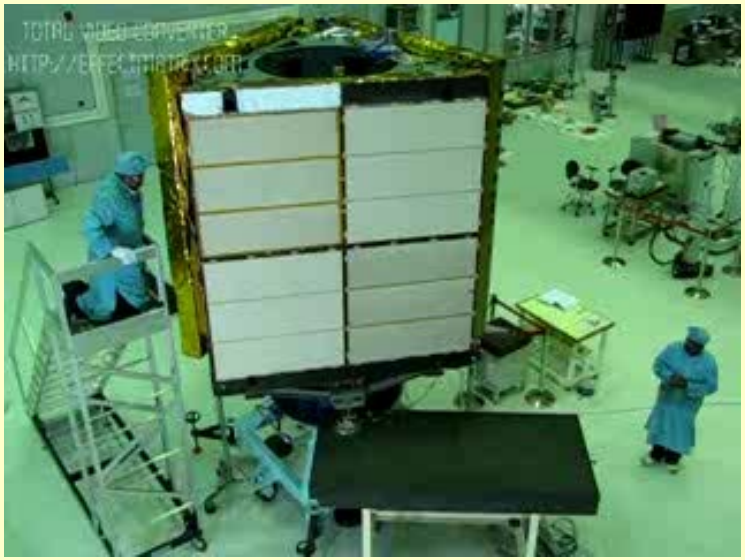


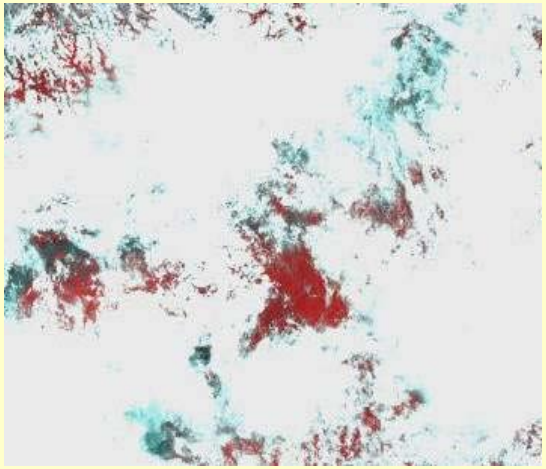
Crop Classification using HySI Data

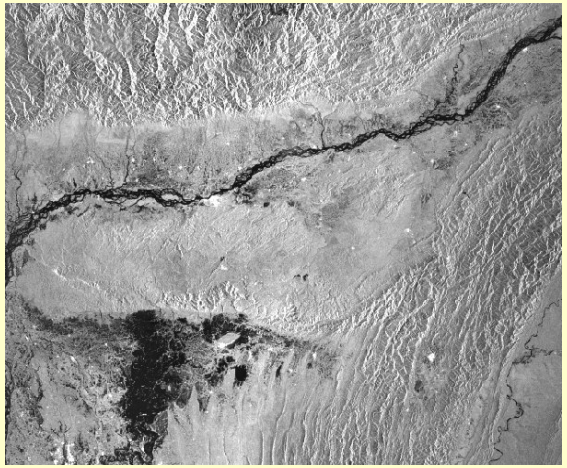


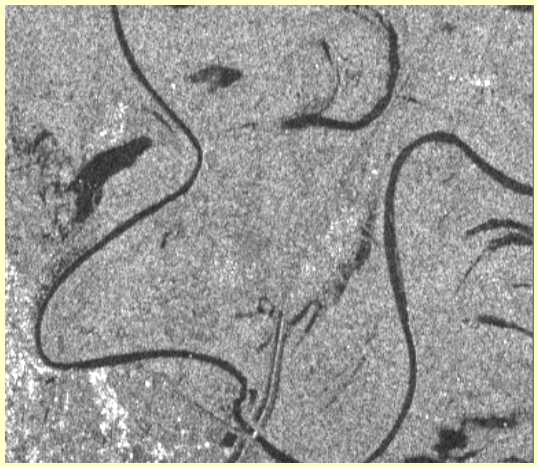
RISAT-1

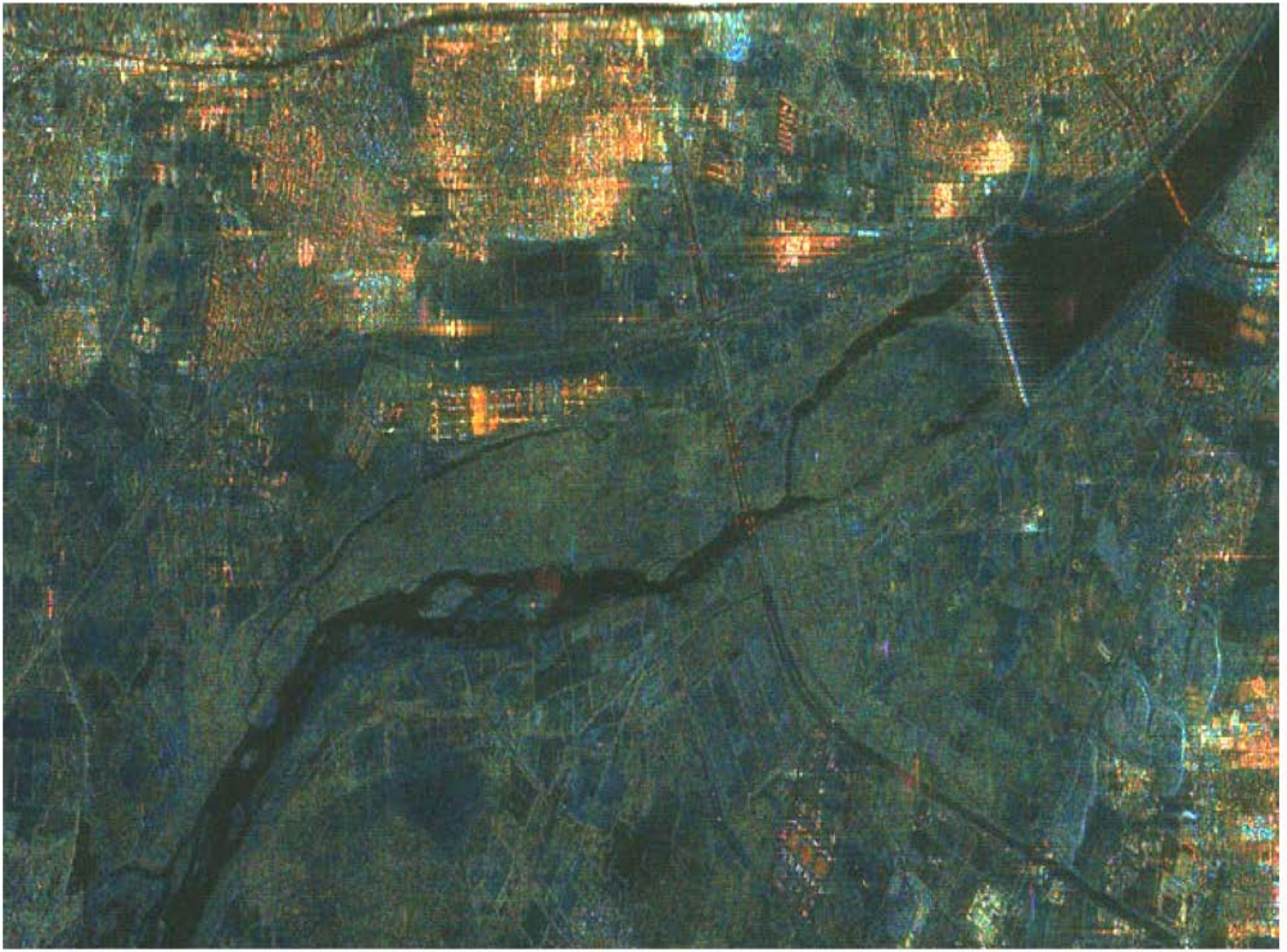
- C-band SAR
- Single/dual/quad polarisation
- Imaging with 1-50m resolution
- 10-240 km SWATH









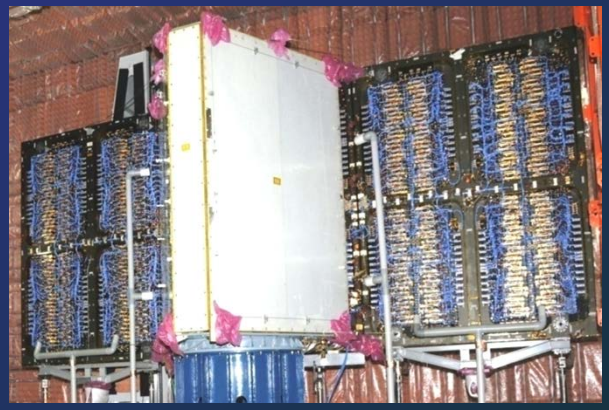


Radar Imaging Satellite (RISAT-1R)

- Swath: 30-40-240 (in Km)
- Resolution:1- 3-9-25=50 (m)
- C-band SAR with active-antenna
- Electronic beam steering
- Single/dual/quad polarization

Multi Resolution
Multi Swath
Multi-Polarization

→ Scan-SAR, Strip-Map, Spot-Light



Spot Mode: = 1 m, σ_0 = -16dB

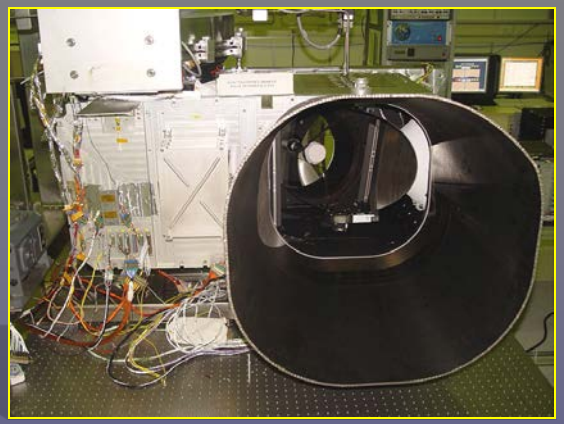
Stripmap Mode: 3 - 6 m, σ_0 = -17dB

ScanSAR Mode1: 25 m, σ_0 = -17dB

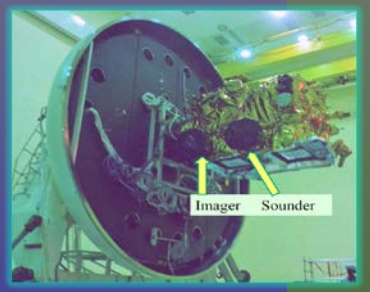
ScanSAR Mode2: 50 m, σ_0 = -17dB

INSAT-3D Met. Payloads

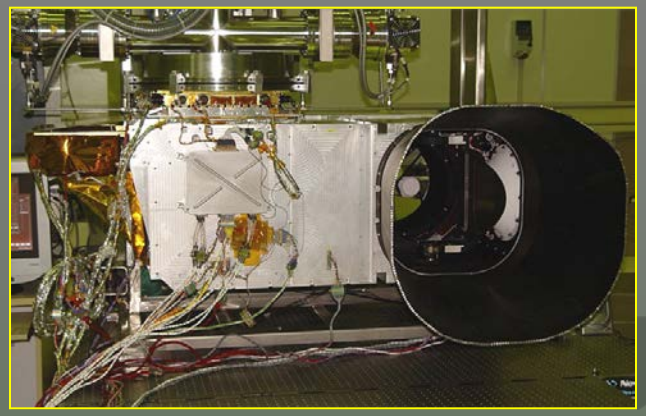
6 channel Imager



- Visible to Thermal IR
- 1KM to 8KM IGFOV
- Half hourly earth coverage
- Flexible scanning modes
- Programmable number of lines and frame repeats
- Improved Blackbody calibration scheme
- Image motion & mirror motion compensation

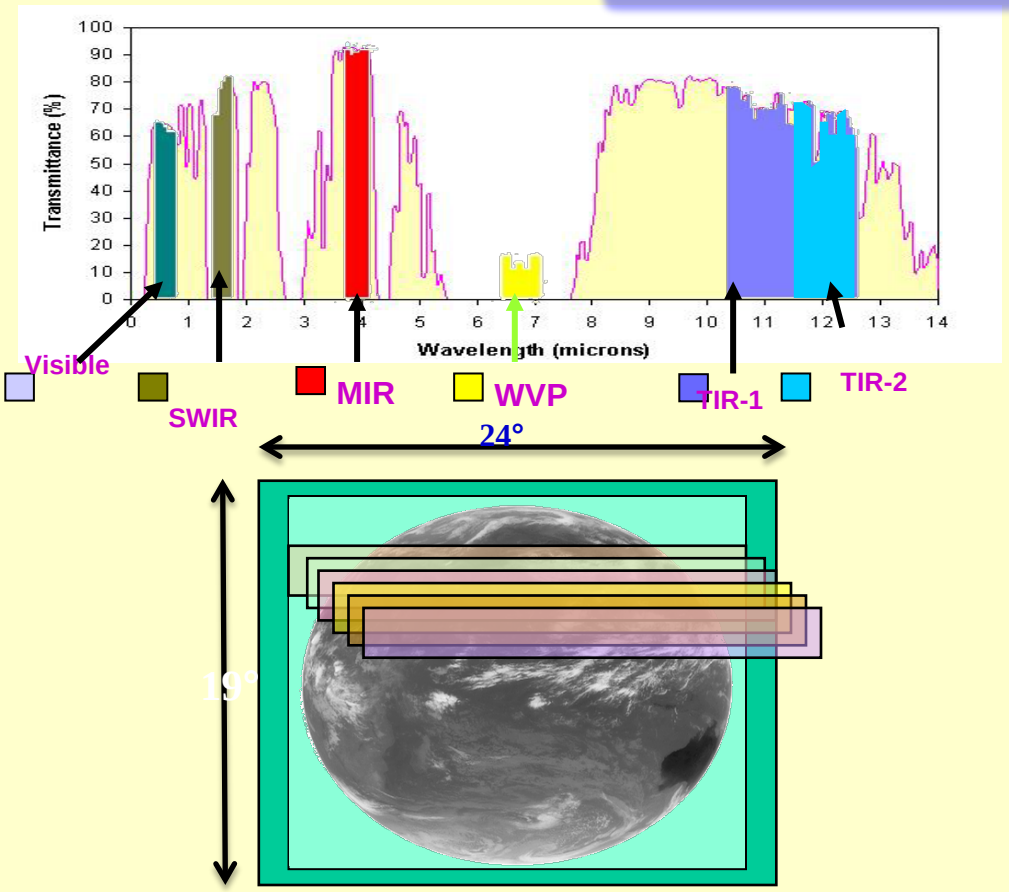


19 channel Sounder



- Visible to Lon. Wave IR
- Fully programmable East-West and North –South Scan pattern
- Programmable dwell time for East-West scan step motion
- Automatic space view every 2 min and Blackbody view every 30min.
- 10KM IGFOV, 14bits digitization
- Image motion & Mirror motion compensation

6 Channel Imager



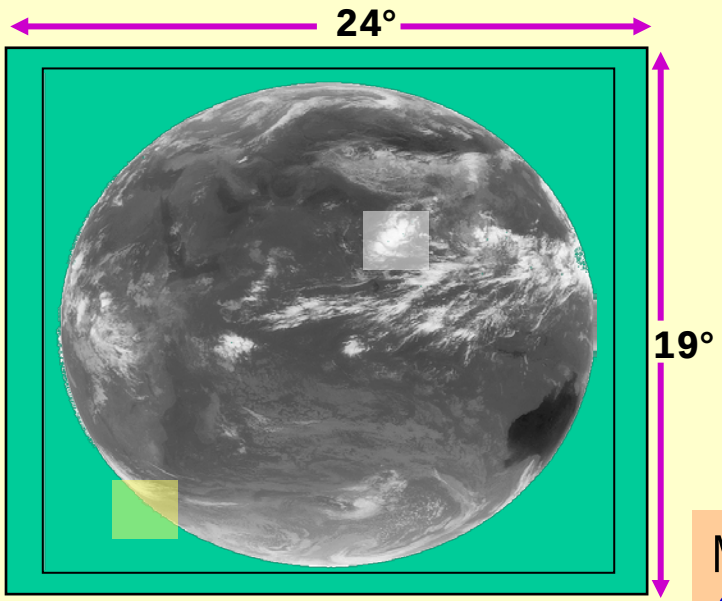
Channel (NEΔT@300K)	Spectral Band (μm)	Spatial Resolution at Nadir (km)
VIS (SNR>150)	0.55-0.75	1 km
SWIR (SNR>150)	1.55-1.70	1 km
MIR (1.4K)	3.80-4.00	4 km
WV (1.0K@230K)	6.5-7.1	8 km
TIR-1 (0.35K)	10.3-11.3	4 km
TIR-2 (0.35K)	11.5-12.5	4 km

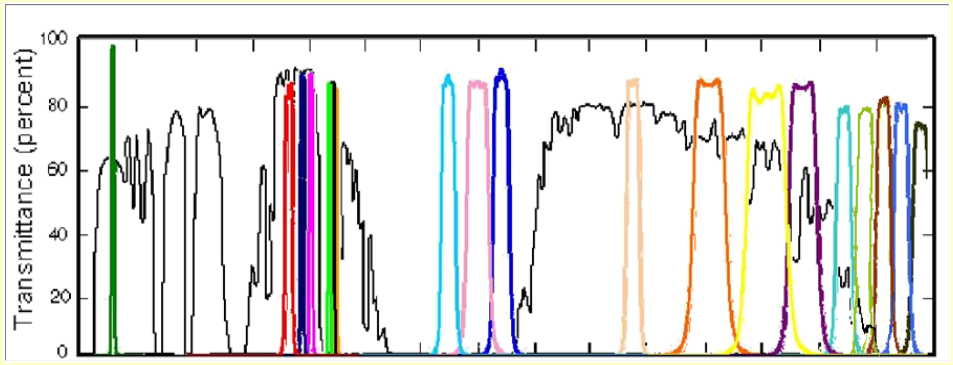
Scan Modes:

Normal: Full Earth Disk, 18°x18° in 24°x19° FOR (<27min)

Programme: No. of Scan lines and No. of Image repeats programmable. Can be placed anywhere in FOR

19 Channel Sounder





Sounder Modes:

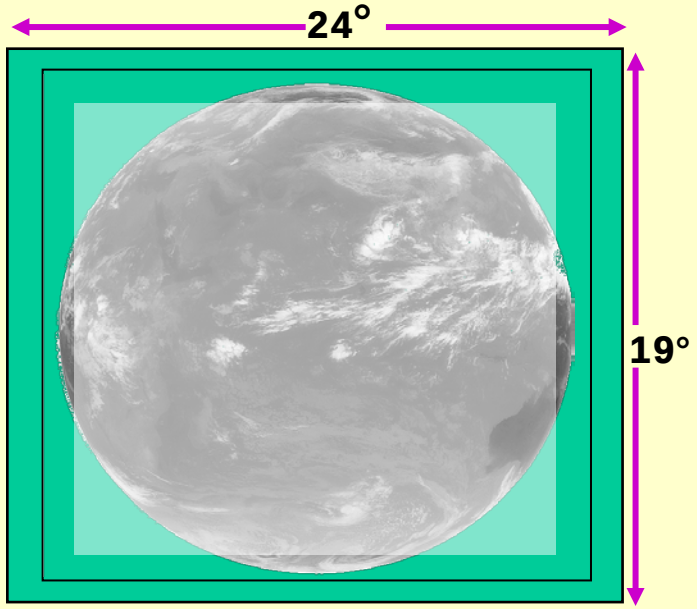
Programmable Sounding Area:

Programmable Space view Direction selection

Selection of Dwell time on each scene: 0.1, 0.2 or 0.4s

Minimum: 1° x 1° (640x640KM) in 1.7min, anywhere in FOR of 24° x19 °

Maximum: 15° x 15° (9600KMx9600KM) in ~400min, anywhere in FOR



Megha-Tropiques *(ISRO-CNES Collaboration)*

Studying water cycle and energy exchanges in Tropical-belt

- **MADRAS:**
  - Precipitation and cloud properties
  - Total-power radiometer with Conical scanning
  - 5 frequencies (18.7GHz – 157GHz)
- **ScaRAB:** Outgoing fluxes at TOA
  - Four Channel Earth Radiation budget at 0.5-0.7 µm, 0.2-4 µm, 0.2-50 µm & 10.5-12.5 µm
  - Resolution: 40 Km, Swath: 2242 Km
- **SAPHIR:** Water vapour profile
  - mmW HSU at 183 GHz, 6-Ch Sounder
  - Brightness-Temperature 4K-313K
  - Resolution: 10 km & Swath: 1705 km
- **ROSA:** GPS based Two Frequency Receivers L1 (1575.42 MHz) & L2 (1227.60MHz)

SAPHIR

SCARAB

ROSA

SARAL: Satellite for Argos and Altika

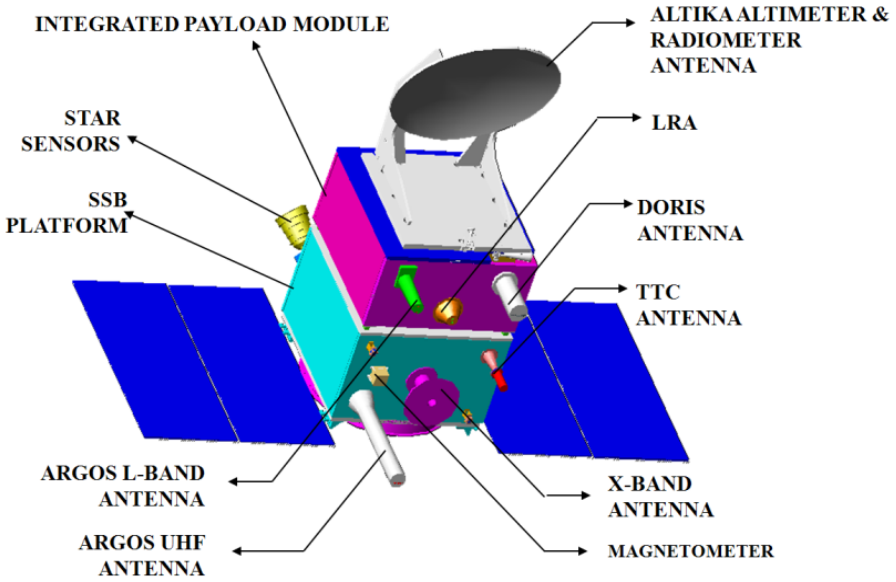
- To provide altimetric measurements designed to study ocean circulation and sea surface elevation.
- Marine meteorology and sea state forecasting, operational oceanography, seasonal forecasting, climate monitoring and climate research.

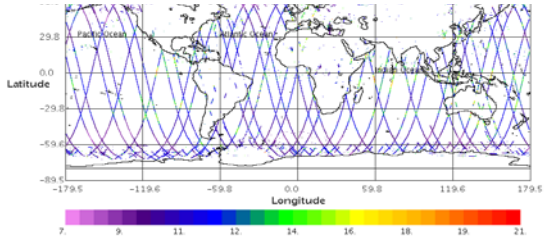
Argos

Satellite based system collects environmental data from autonomous platforms

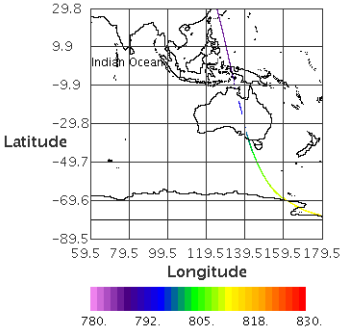
Altika

- A Ka Band altimeter (35.5 – 36 GHz)
- A dual frequency radiometer (24 / 37 GHz)
- A common antenna shared by Altimeter & Radiometer (1 meter dia)
- LRA (Laser Retro - Reflector Array)
- DORIS instrument (Doppler Orbitography & Radio positioning Integrated by Satellite)

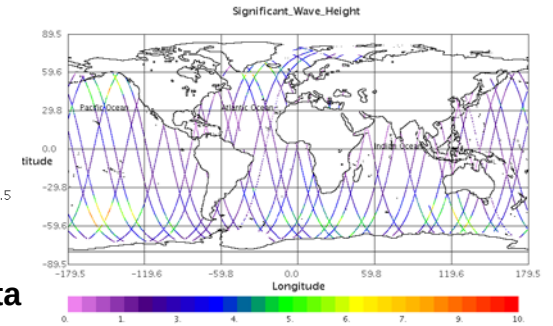




Altimeter σ_0 Data

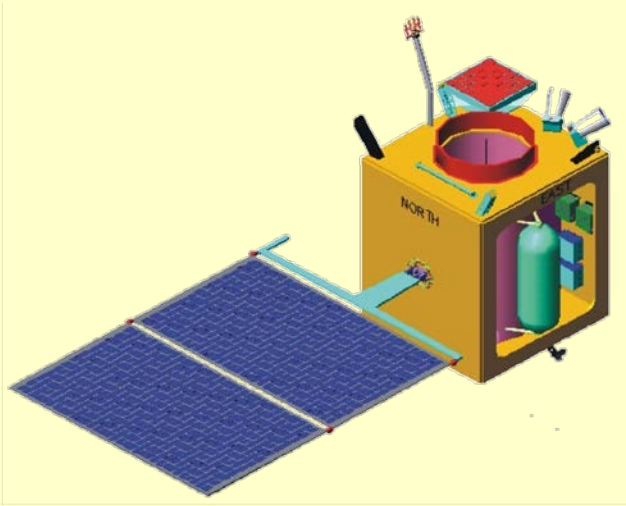


Envisat Alti. Range Data



Envisat Altimeter SWH Data

GISAT



High Resolution Imaging Sensors on GEO Platform

- High resolution Multi-spectral VNIR

  Ground Resolution : 50 meters

- Hyper-spectral VNIR

  Ground Resolution : 500 meters

- Hyper-spectral SWIR

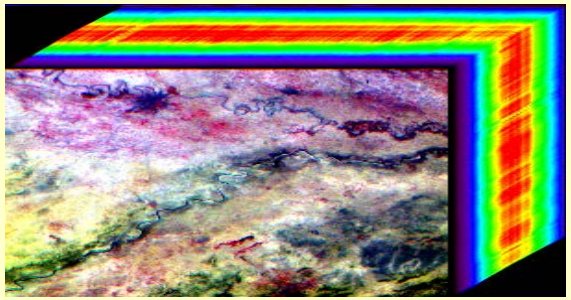
  Ground Resolution : 500 meters

- Multi-channel IR

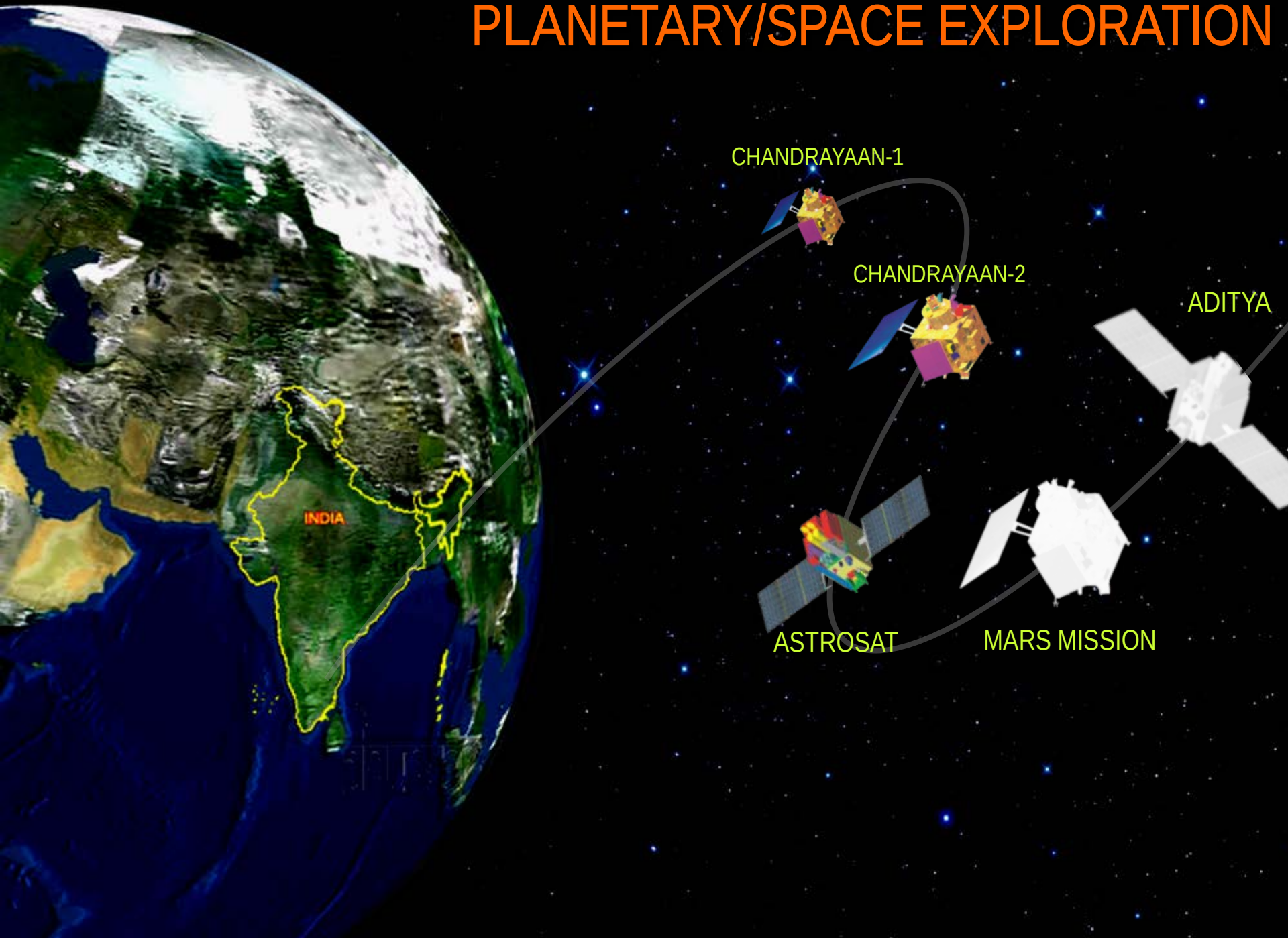
  Ground Resolution : 1500 meters

Scanning Modes:

- Full globe (18x18 deg)
- Sub continent (10x12 deg)
- User defined area scanning

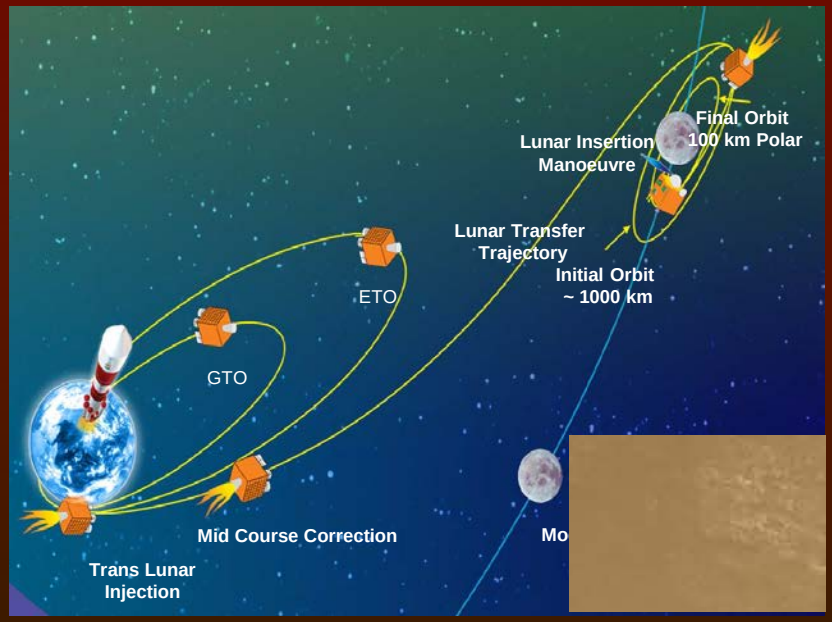


PLANETARY/SPACE EXPLORATION



Chandrayaan-1

Guidance & Control System



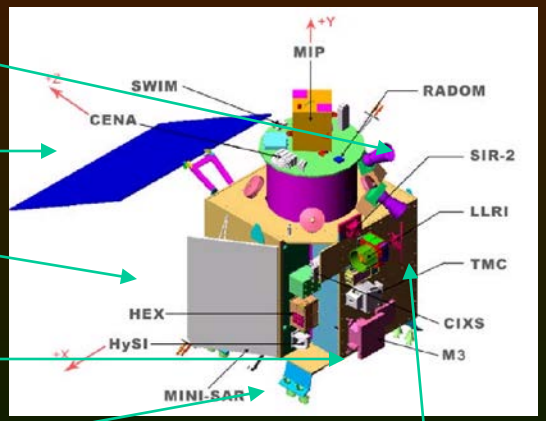
Altimeter

Star Trackers

Sun Sensors

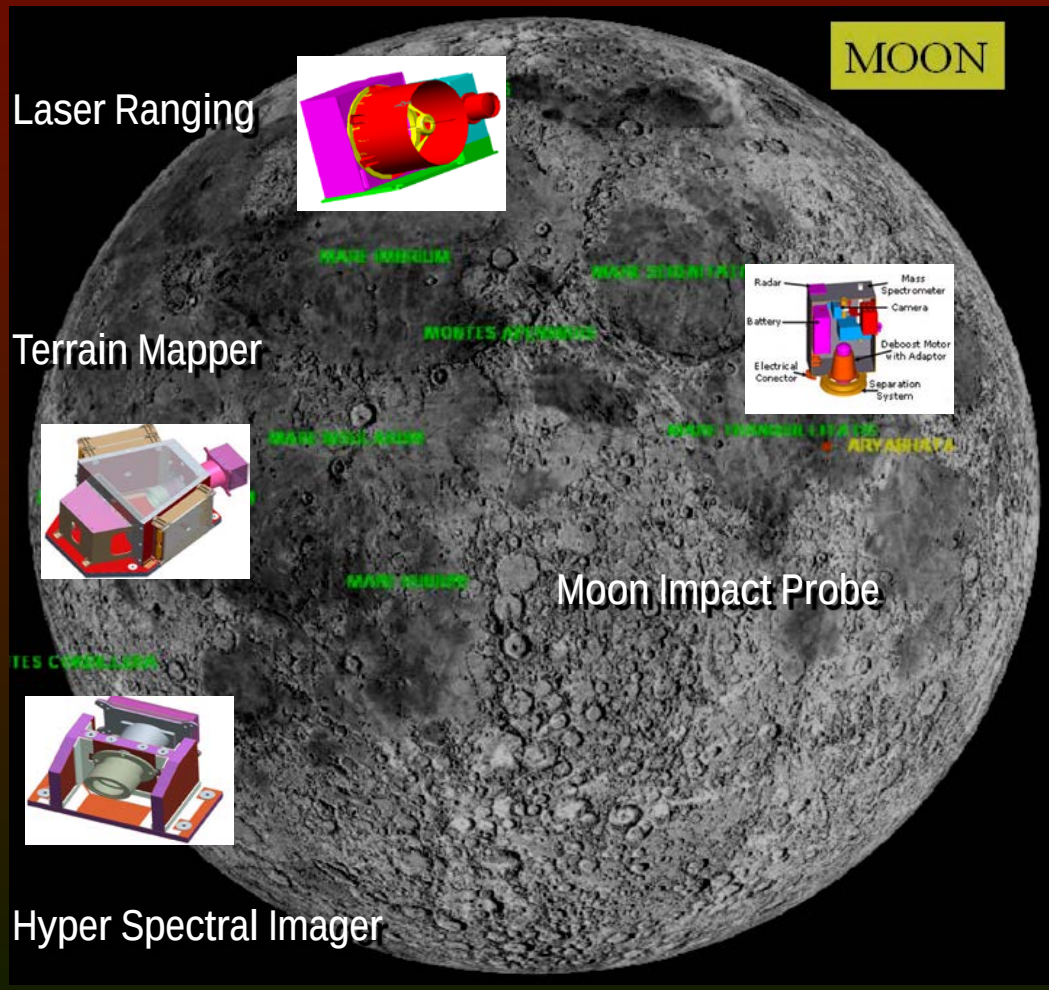
Accelerometer

Gyroscope



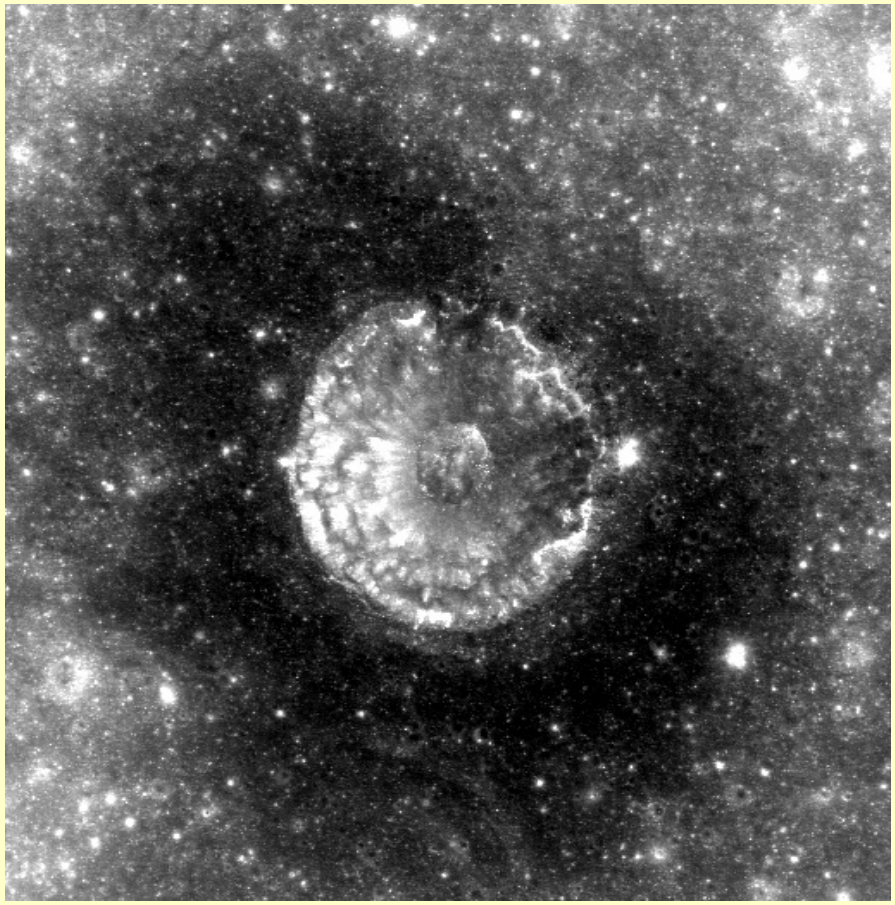
Pressure & Temp Sensors

Payloads

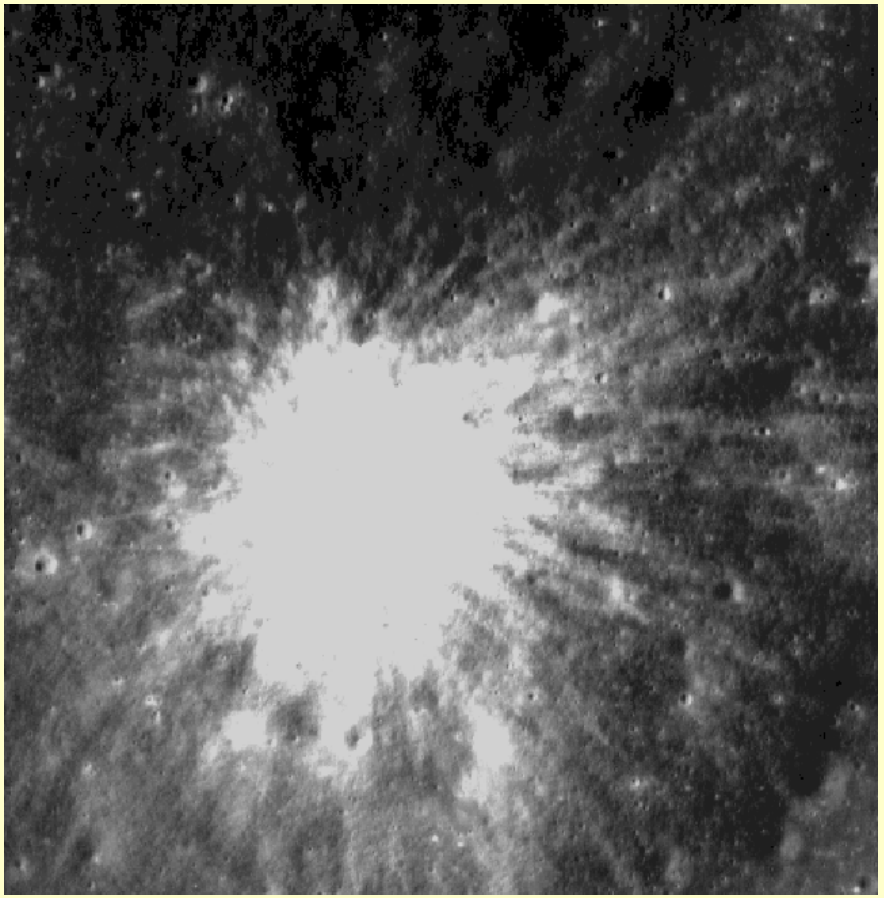


TMC images of Chandrayaan-1

Lunar Impact Craters



Dark Haloed crater



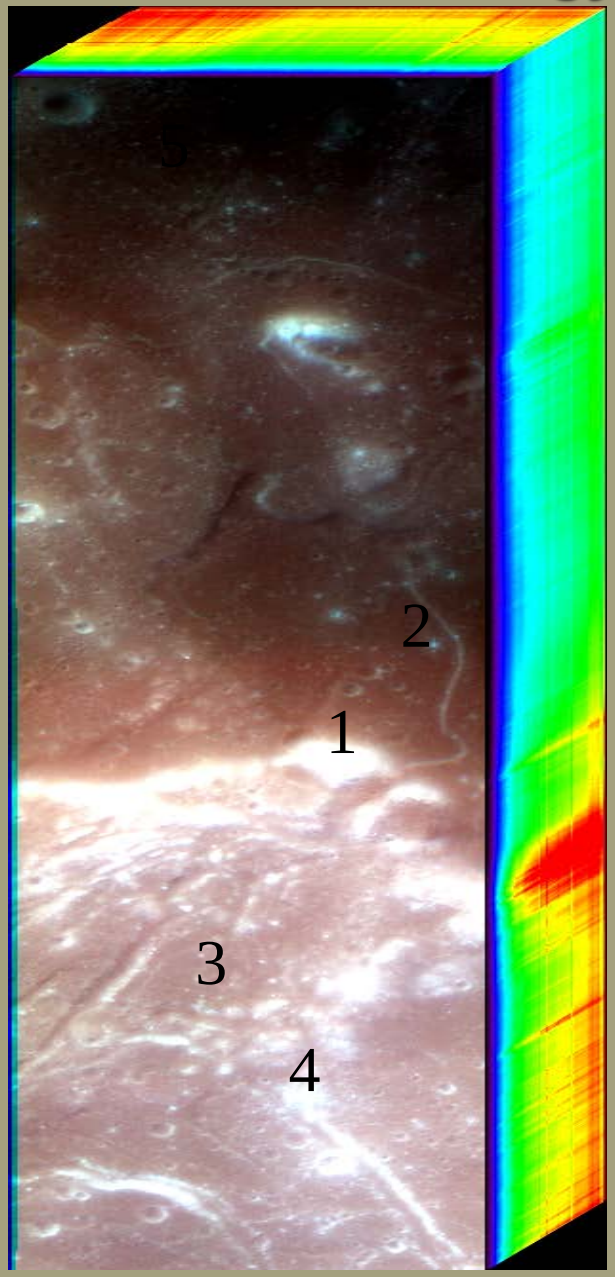
Ray Crater

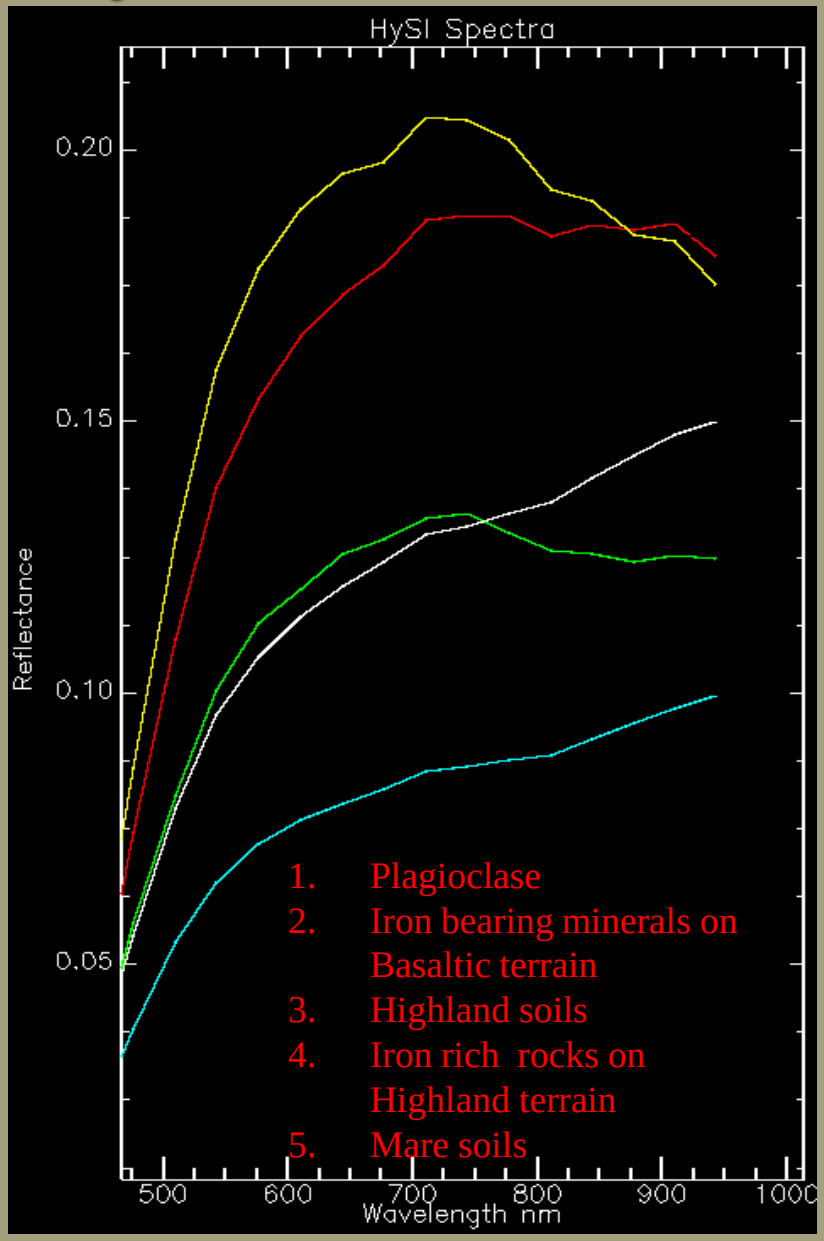
Lunar Mineralogy : HySI data

Mare Orientale is one of the youngest basin on the Moon surface. Location of Mare Orientale is shown as red dot on extreme left Lunar composite image.

The HySI image from Chandrayaan-1 data represent sixty four colour of Lunar surface. The reflectance curves generated from HySI data helps us to identify highland and basaltic rocks on Moon.

Detection of Lunar rock types using HySI reflectance data

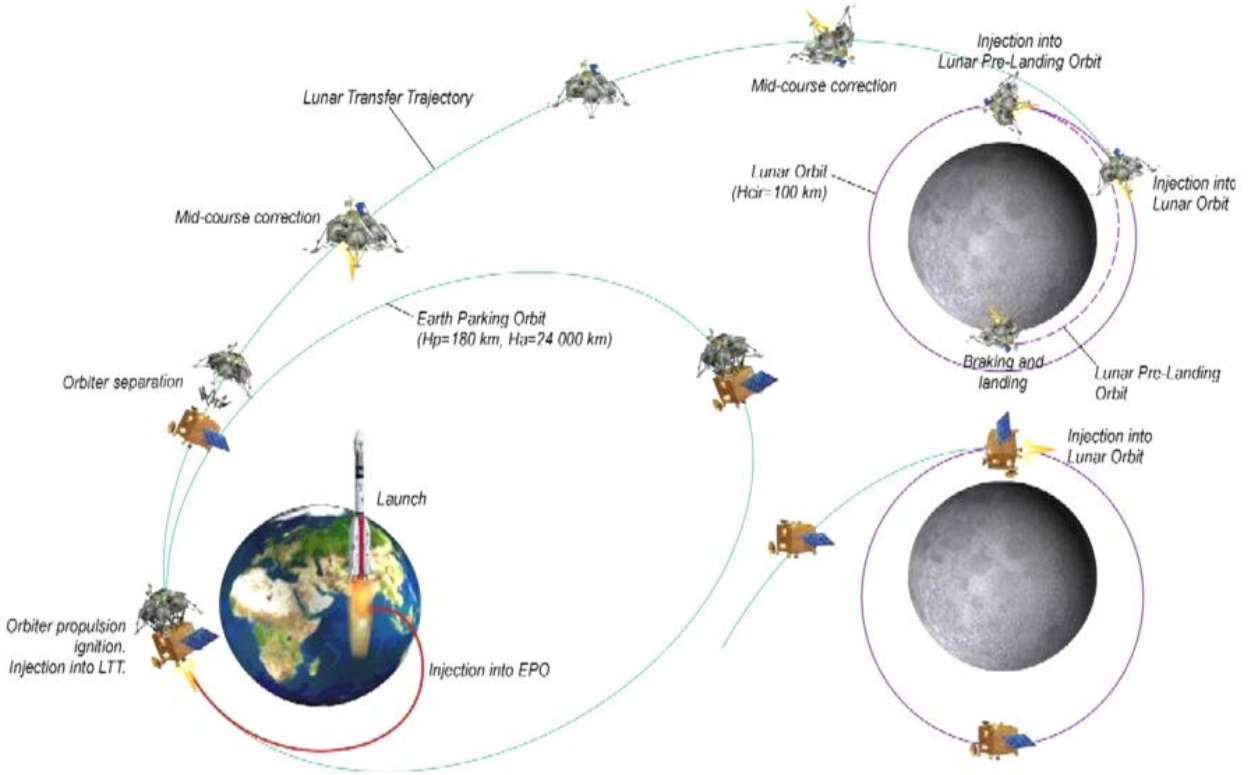




Chandrayaan-2 Mission

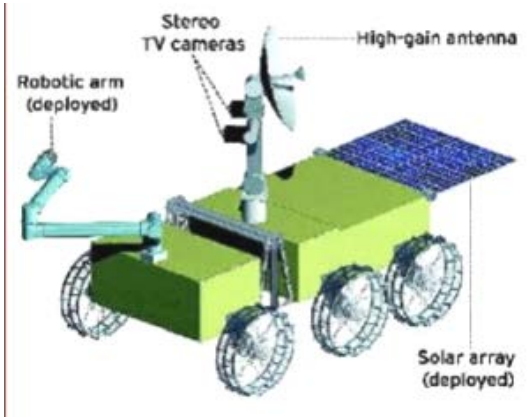
- GSLV launch with a weight of ~2,650 kg
- Orbiter & Lander
- Indian Rover
- Orbiter Payloads

  - Soft X-ray spectrometer
  - L & S band mini SAR
  - Imaging IR spectrometer
  - Neutral mass spectrometer
  - Terrain Mapping Camera



- Rover Payloads

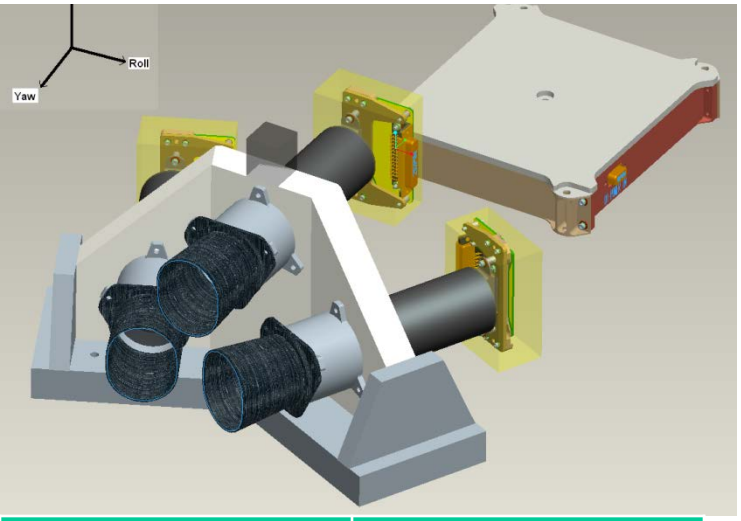
  - Laser Induced Breakdown spectroscopy
  - Alpha particle induced X-ray spectroscopy



Chandrayaan-2 Electro-Optical Payloads

Micro Camera

Terrain Mapping Camera-2 (TMC-2)



Camera weight	**4 Kg**
FOV	**1° along track**
	6.5° across track
Imaging	**views: +25° , 0° , -25°**

Size table

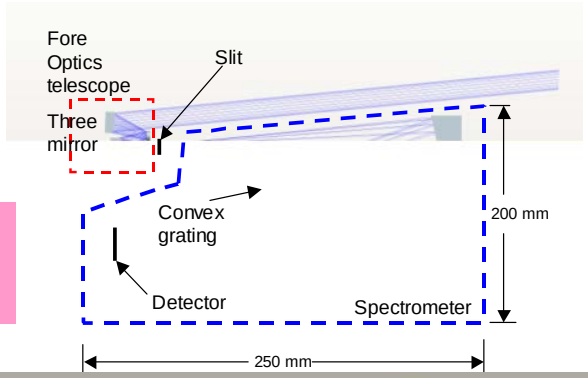
Direction	EOM	Elect. Pkg.
YAW	260 mm	192 mm
PITCH	200 mm	35 mm
ROLL	345 mm	172 mm

Footprint: 10 m X 10 m
Along-track sampling: 5 m
Swath : 40km

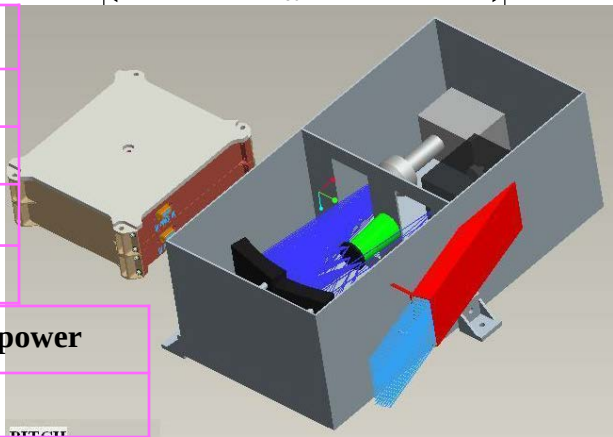
- Event Monitoring Camera
- Rover Arm Camera (RAC)

	Camera Head (each)	Processing Electronics (for 2 Camera head)
Regulated Power (W)	500 mW	800 mW
Size (mm x mm)	40 X 40 X 20	100 X 100 X 30
Weight (g)	<30	<300

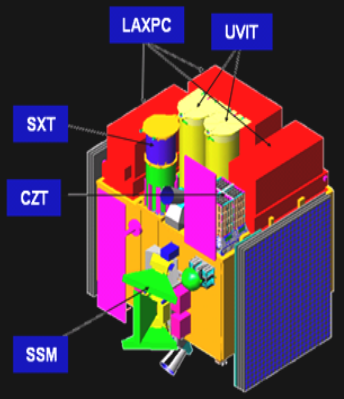
Imaging IR Spectrometer (IIRS)



GIFOV	**80m**
Swath	**40km**
Spectral Range	**0.8-5.0 μm**
Spectral Resolution	**<20 nm**
Max. spectral bands	**256**
Regulated Power	**7W + Detector cooler power**
Weight	**6.5kg**



ASTROSAT



1. Large Area Xenon Proportional Counter (LAXPC)
2. Scanning Sky Monitor (SSM)
3. Cadmium Zinc Telluride Imager (CZT)
4. Soft X-ray telescope (SXT)
5. UV Imaging Telescope (UVIT) jointly developed by ISRO & CSA
6. Charged Particle Monitor (CPM)

ASTROSAT is a national multi-wavelength space borne astronomy observatory, which would enable simultaneous observations of the celestial bodies, cosmic sources in X-ray and UV spectral bands. The uniqueness of ASTROSAT lies in its wide spectral coverage extending over visible (3500-6000 Å), UV (1300-3000 Å), soft X and hard X ray regions (0.5-8 keV; 3-80 keV).

MARS Mission

- Study of Martian surface
- Martian Atmosphere and Ionosphere
- Radiation & particles in Martian environment

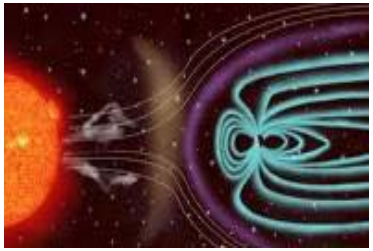
Depart Earth Orbit @	Transfer Days	Arrival in MARS Orbit	
26-11-2013	299	21-09-2014	PSLV-XL
10-01-2016	275	11-10-2016	--
17-05-2018	239	11-01-2019	PSLV -XL

Studies of Mars & Phobos

Technically Challenging LONG duration (~ 300 days travel) Deep-Space Mission

ADITYA

A Space based Advanced Solar Coronagraph to study solar Corona in Visible and NIR wavelengths



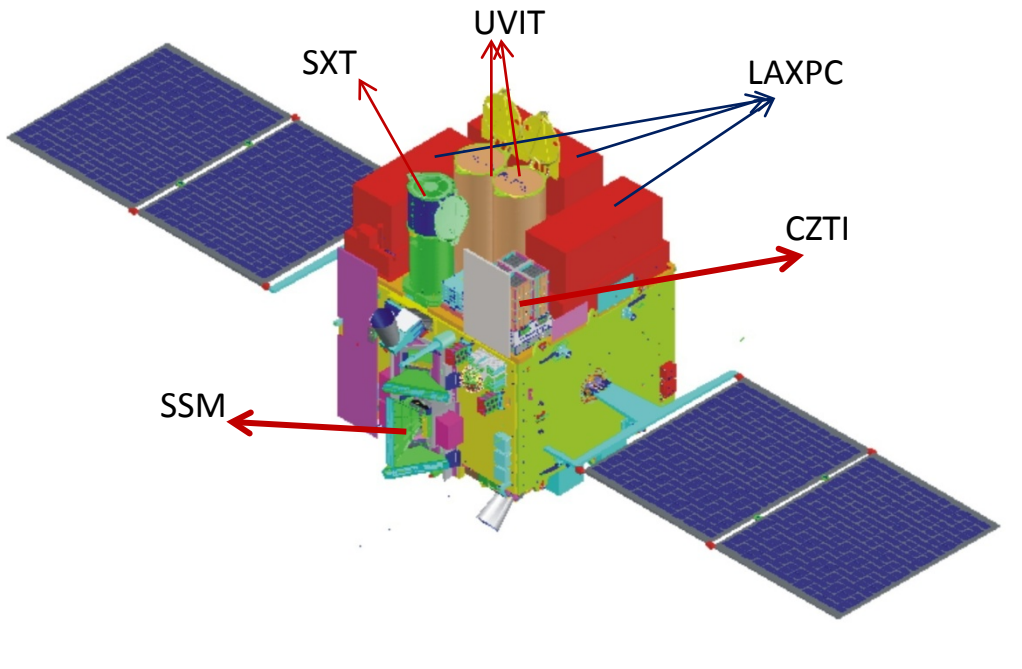
Observe Oscillations of coronal structures
Polarization of light: Study of magnetic field Detect "start" of coronal mass ejection

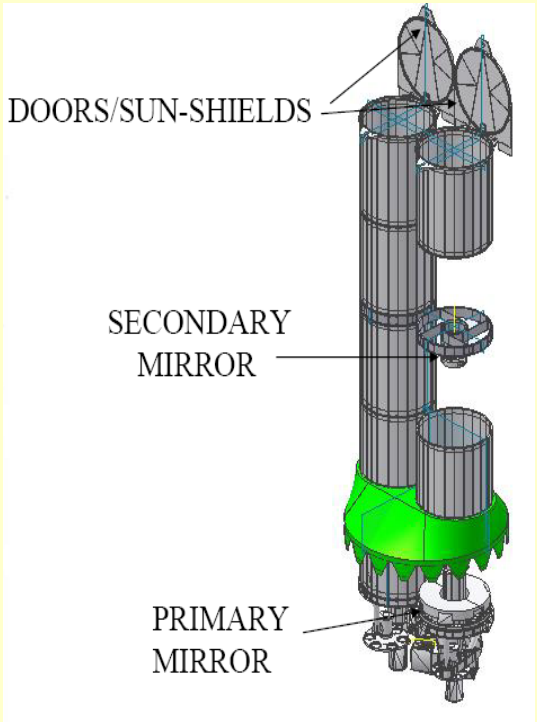
inputs for Space-Weather

ASTROSAT – *versatile space based observatory*

India's first dedicated multi-wavelength astronomy satellite with a capability to observe target sources in wide spectral coverage extending over visible, ultraviolet, soft x-ray and hard x-ray regions with co-aligned instruments simultaneously

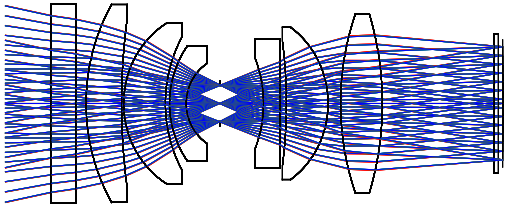
- **Large Area X-ray Proportional Counters (LAXPCs)**
- **Cadmium zinc Telluride Imager (CZTI)**
- **Soft X-Ray Telescope (SXT)**
- **Ultraviolet Imaging Telescope (UVIT)**
- **Scanning Sky Monitor (SSM)**





OPTICAL SYSTEMS

➢REFRACTIVE



Double Gauss

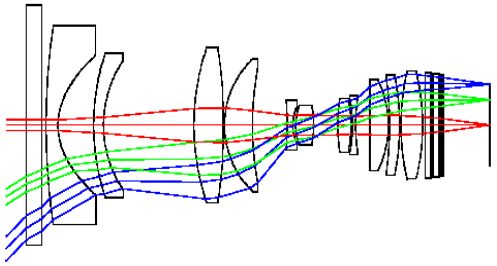
FOV <40°

EFL < 0.7m

Telecentric

FOV < 90°

EFL:very small focal lengths~25mm

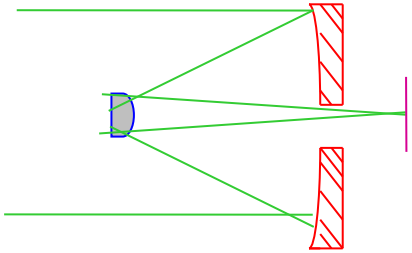


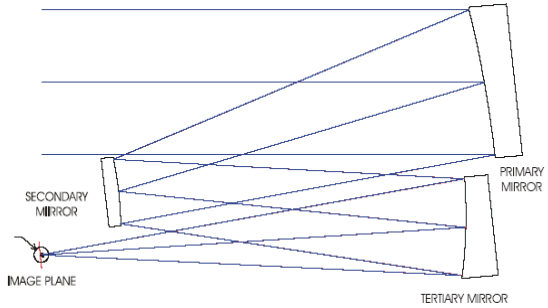
➢ALL REFLECTIVE

Cassegrain

FOV < 3°

EFL:Large focal length~15m





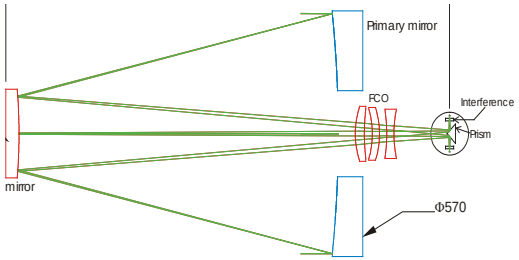
Three-mirror Anastigmat

UNOBSCURED)

FOV ~ 10°

EFL< 3 m

➢CATADIOPTRIC



Ritchy Cassegrain with FCO

FOV ~ 3°

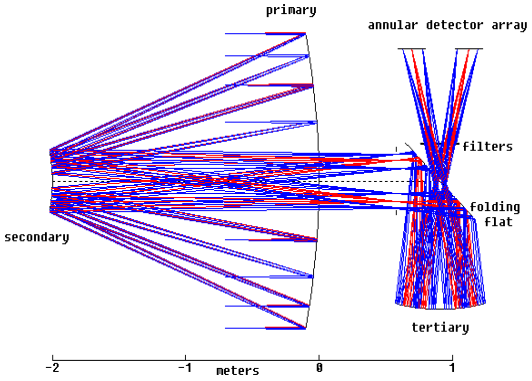
EFL: Large focal length~15m

➢MULTI-MIRROR

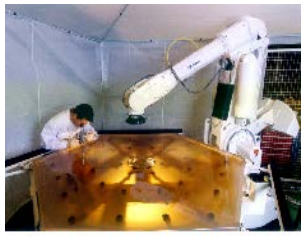
Korsch TMA

FOV < 3°

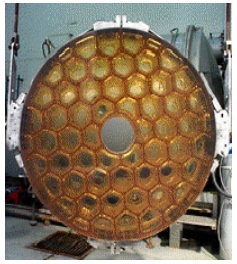
EFL: Very Large focal length~ 30m

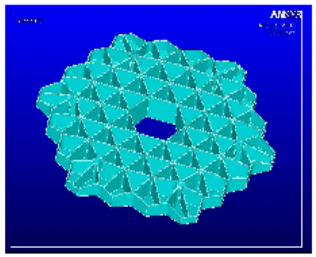


Optical System - Technologies

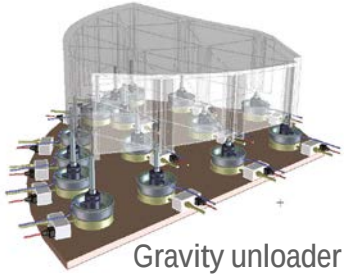


Computer Aided Polishing





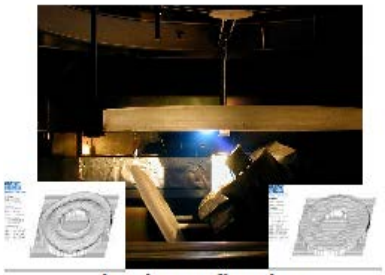
F E computation



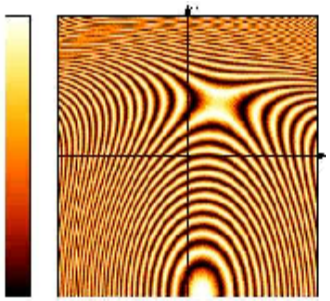
Gravity unloader concept

- Optical Fabrication
  - Computer aided polishing
  - Ion Beam figuring
  - Stressed mirror polishing
- Light Weighting
  - Scooping from rear
  - Honey Comb structures
  - Frit bonding
- Opto-Mechanical Engineering
  - Optical performance simulation
  - FE computation
  - Gravity unloaders for large mirrors
- Optical Metrology
  - Mirror testing using CGH
  - Interferometric aided alignment

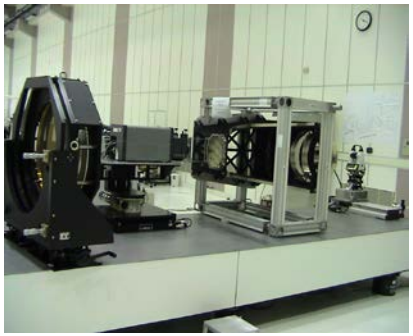
Honey comb structure



Ion beam figuring



Optical performance simulation

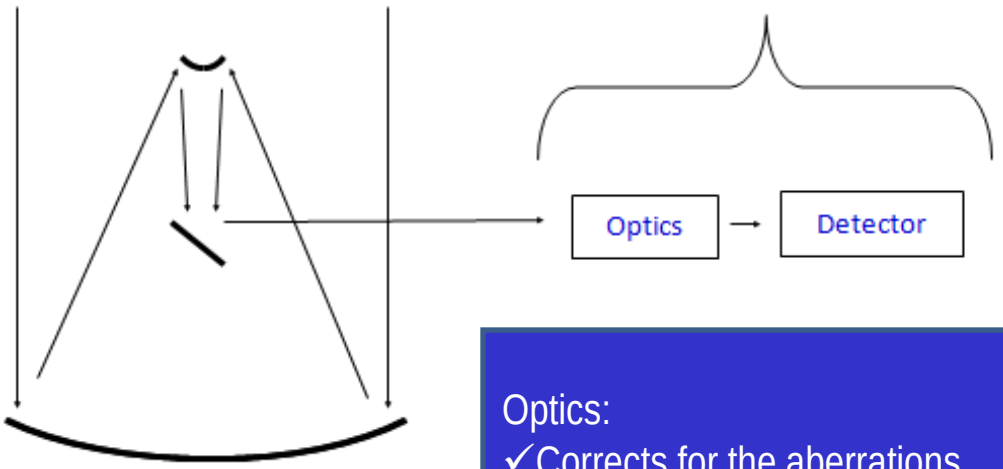


Interferometry alignment

Near ideal electro-optical system performance

Telescope to collect and focus light

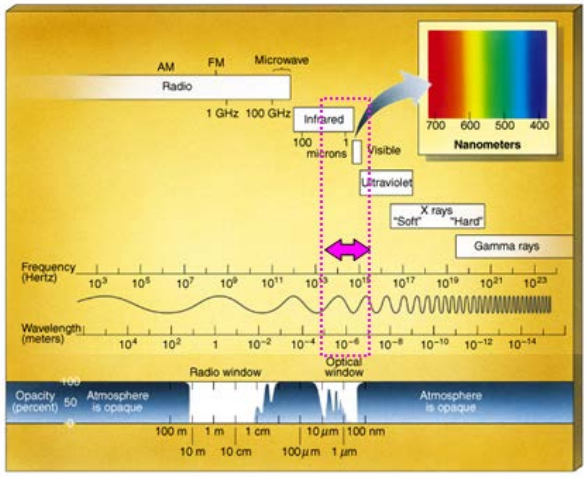
Instrument to measure light



Ideal Detector:
- ✓100% Photons Detected with 63% MTF Nyquist
- ✓Measures Photon wavelength
- ✓Time of Photon arrival
- ✓Detects Polarization

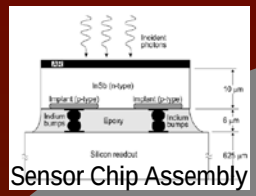
Optics:
- ✓Corrects for the aberrations
- ✓Diffraction limited performance along the field
- ✓Performs Optical filtering
- ✓Polarization selection
- ✓Registered bands

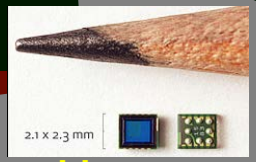
Telescope:
- ✓Collects incoming EM energy
- ✓Defines the spatial resolution
- ✓Diffraction limited MTF
- ✓Negligible Stray light



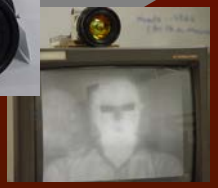
Imaging Sensors
Evolution

Detector	Wavelength (m)
Si	0.2 - 1.1
Ge	0.4 - 1.8
InGaAs	1.0 - 3.8
InSb	1.0 - 7.0
InSb (77K)	1.0 - 5.6
HgSdTe (77k)	1.0 -25.0

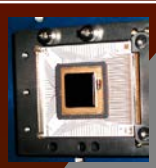




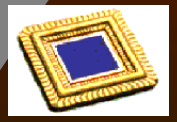
Camera on chip

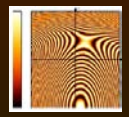


Focal plane array

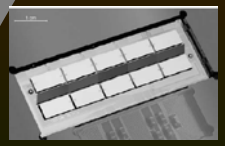


MCT array on Si readout circuit





MCT/CMOS linear array



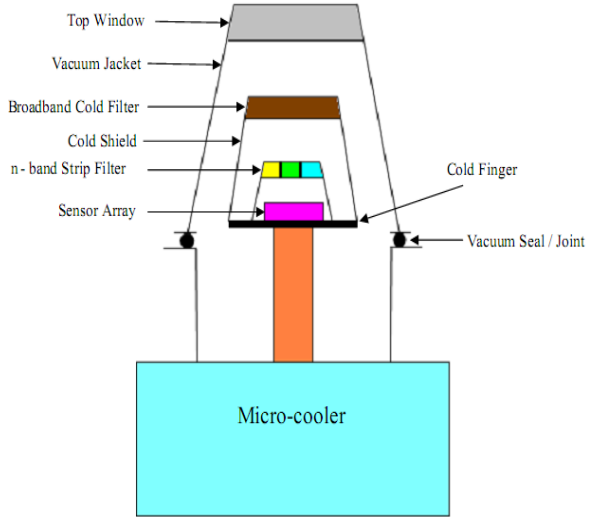
Single/ multi element detector

	Bhaskara	IRS 1A/1 B	IRS 1C/1D/P6	TES/CARTO
Imaging Technology	Frame	Pushbroom		Step & Stare
Resolution (m)	1000	72/36	5	1
Focal Length (mm)	Refractive (10-450)		Reflective (~980)	Catadioptic (~5600)
Aperture (mm)	50 – 140		220	700
Detector	Vidicon / vacuum tube	Linear array CCD / solid state		
Data rate (Mbps)	~0.1	5-20	~100	~200
Platform	Spin stabilised	3-axis stabilised		Agile

Multi-spectral imager with high resolution (spatial, spectral and radiometric)

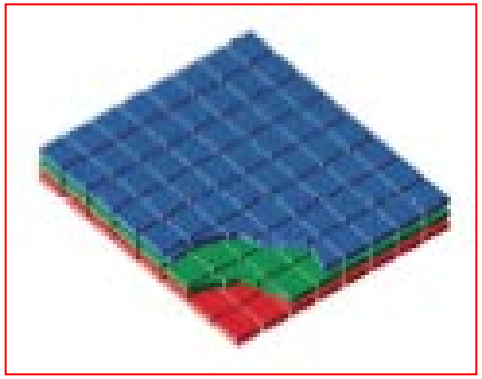
Detector:

1) Multi-linear detector for high BBR
2) Mechanically/optically butted array for Large swath
3) Area array overlaid with filter operated as multi-linear array
4) Multi-band detector

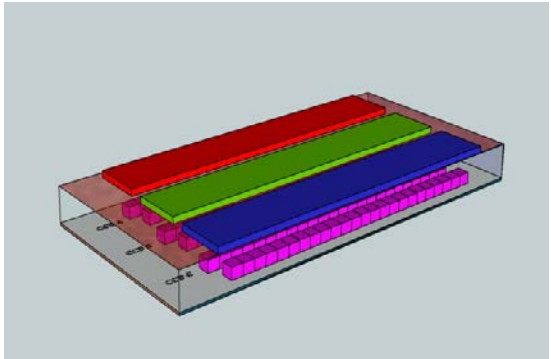


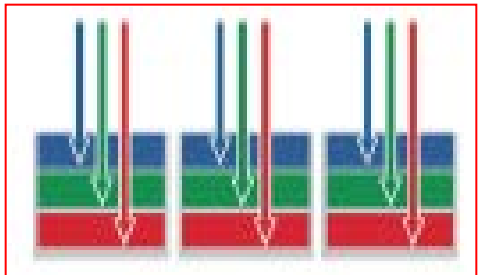
Filter:

- Discrete filter
- Strip filter
- Filter overlaid on detector die



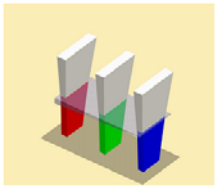
3 Separate Silicon Layers at Each Pixel

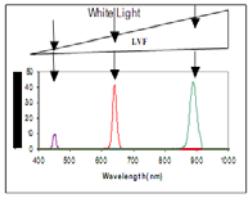


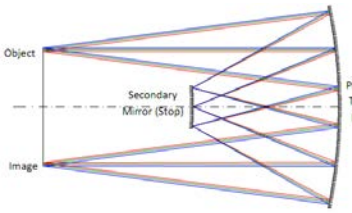


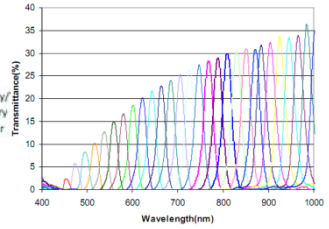
Different Colours Absorbed at Different Depths

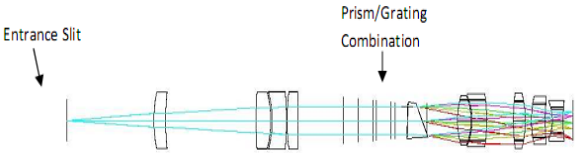
Hyper-spectral

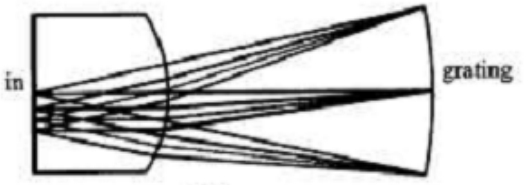


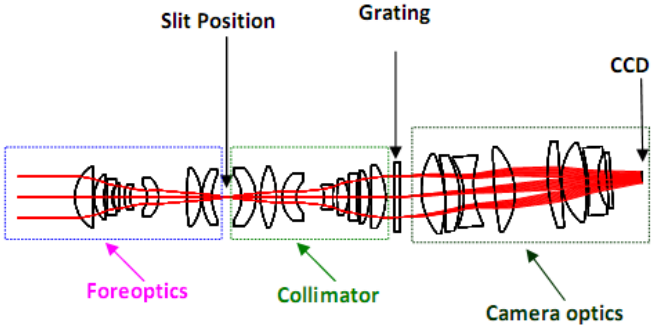


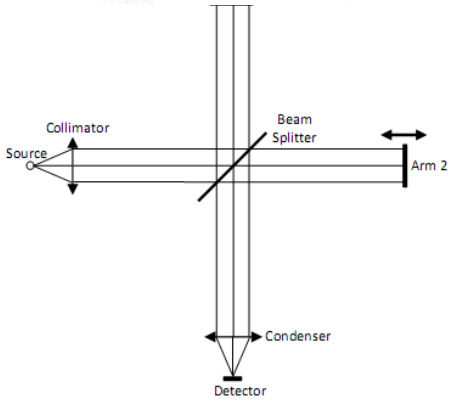






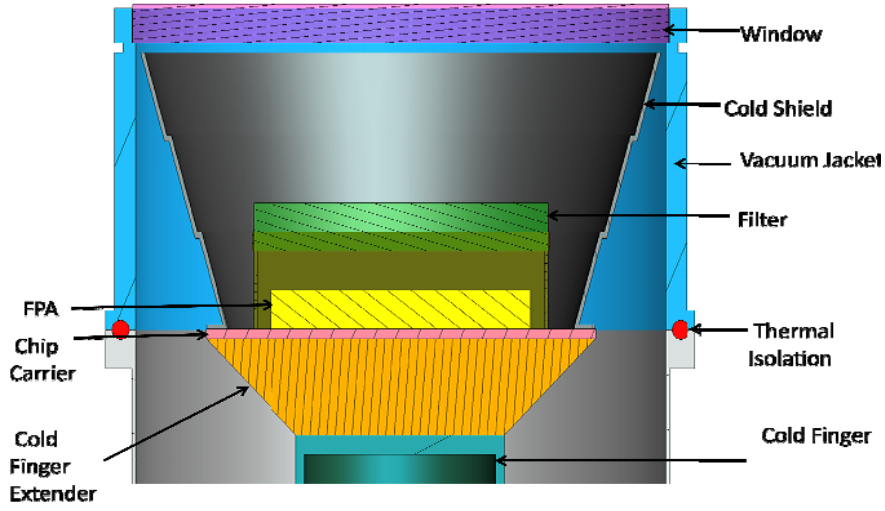






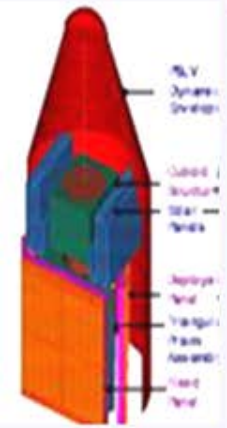
Background can be reduced by

- Low emissive mirrors and grating
- Cold shield and cold stop at the exit pupil of the optics
- cooling the spectrometer optics and its structure
- Cooled Linear variable filter (LVF)
- Cooled Multiple Strip filter

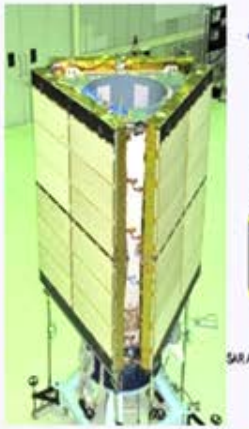


Properties	Grating		Prism		FT Spectrometer		Wedge Filter	
Spectral Resolution	High	+	Medium	0	High	+	Medium	0
Throughput	High	+	Medium	0	High	+	Medium	0
Spectral Range	Broad	+	Narrow	-	Broad	+	Medium	0
Sensitivity to S/C motion	No	+	No	+	Yes	-	No	+
Moving Parts	No	+	No	+	No/Yes	0	No	+
Simultaneous acquisition	Yes	+	Yes	+	Yes	+	No	-
Straylight	Low	+	Low	+	High	-	High	-
Complexity	Low	+	Low	+	High	-	Low	+
Distortion	Low/High*	0	High	-	Low	+	Medium	0
Compactness	Medium	0	Medium	0	Low	-	High	+

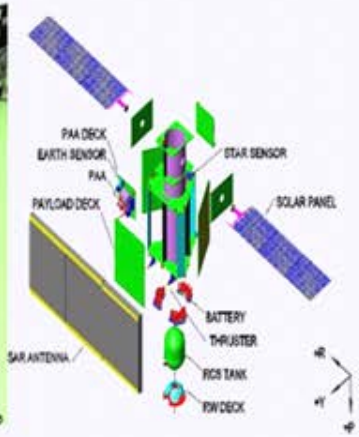
RADAR IMAGING SATELLITE (RISAT-1)



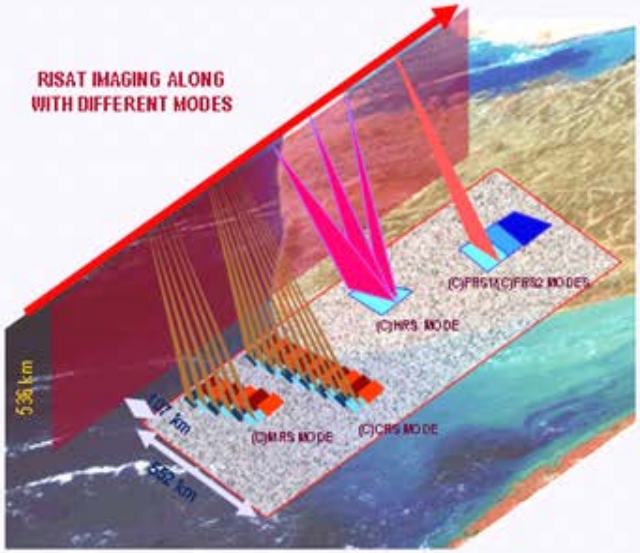
STOWED CONFIGURATION MODEL



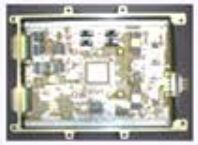
STOWED IN INTEGRATION LAB



SATELLITE EXPLODED VIEW

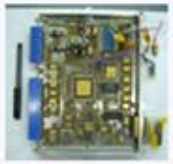


DACS



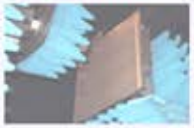
DCG

TR MODULE



ASIC FOR TRC

PLC

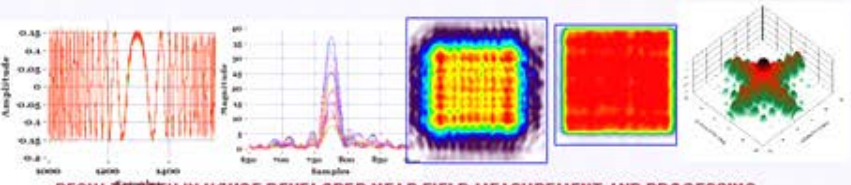


MULTILAYER DUAL POLARISED PRINTED ANTENNA

FEATURES

- First Spaceborne SAR indigenously developed
- C-band SAR catering to diverse applications from Agriculture to high resolution land-mapping
- Resolution from 1m to 50m
- Swath from 10km to 220km
- State-of-the-art Active Antenna with 576 TRMs
- Electronic beam steering covering 107-659km range

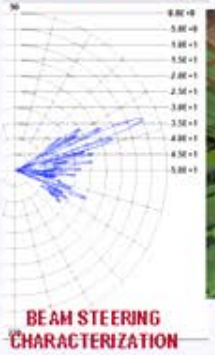
EPC FOR TRM



RESULTS WITH IN-HOUSE DEVELOPED NEAR-FIELD MEASUREMENT AND PROCESSING TECHNIQUES

APPLICATIONS

- Forestry, Flood Mapping, Vegetation, Soil Moisture, Oil Spillage, Disaster Management
- Caters to some applications of L and X band SAR also.



BEAM STEERING CHARACTERIZATION

TIME GATED NEAR FIELD CHAMBER

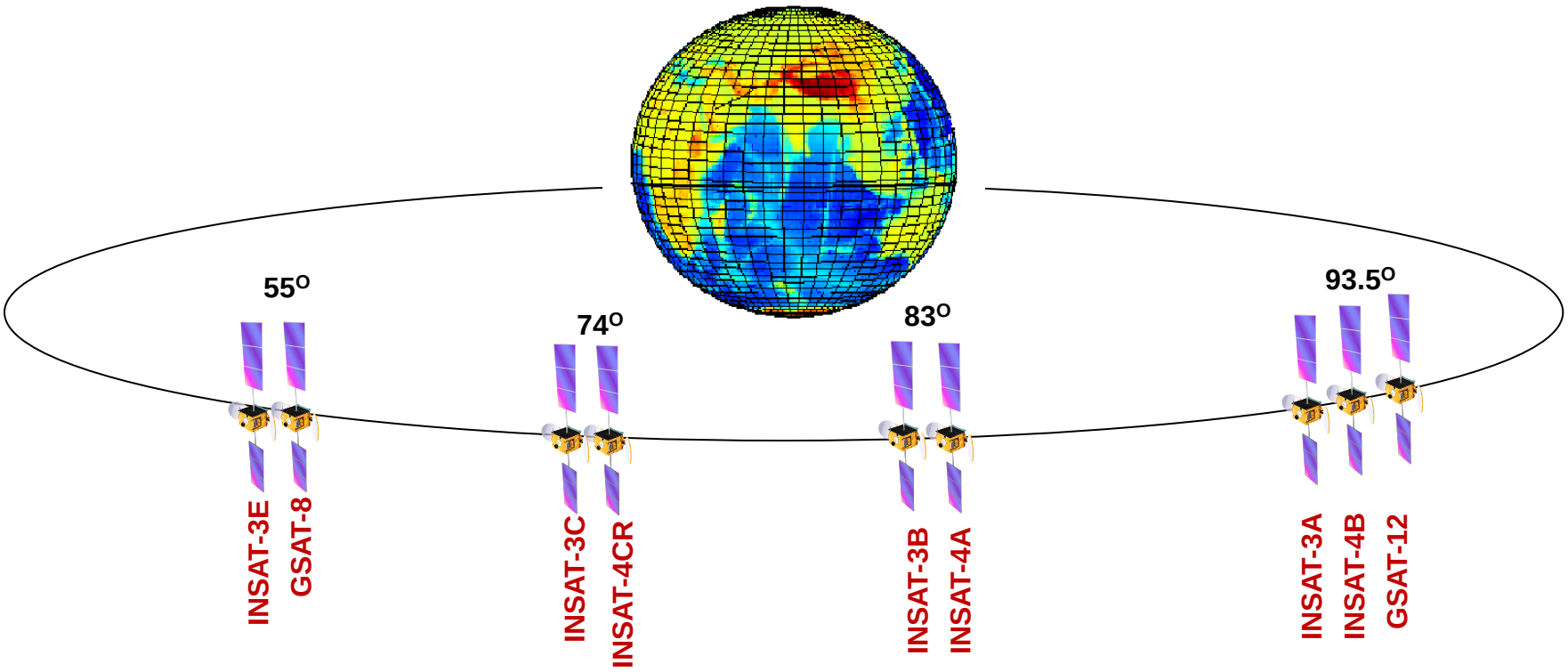
1M X 1M TILE (ONE OUT OF 12 TILES)

SINGLE-TILE HOLOGRAM

TECHNOLOGY EVOLUTION

	OPTICAL			MICROWAVE
	(BHASKARA)	MULTI-SPECTRAL	HIGH-RESOLUTION	RADAR IMAGING
IMAGING TECHNOLOGY	FRAME IMAGER	PUSH-BROOM	STEP & STARE	Synthetic Aperture Radar
RESOLUTION	1000M	72/36M – 5M	0.8M	1M-50M
EM ENERGY COLLECTION	REFRACTIVE (10-450mm)	REFLECTIVE (~980mm)	CATADIOPTRIC (~5600mm)	ACTIVE ANTENNA
DETECTOR	VIDICON/ VACUUM TUBE	LINEAR ARRAY CCD/SOLID-STATE	LINEAR ARRAY CCD/SOLID-STATE	RECEIVE MODULES
ELECTRONICS	CMOS	LSTTL/STTL	STTL/FTTL	ASICS/ FTTL/ FPGA
DATA RATE	~100 Kbps	5-20 Mbps – 100 Mbps	~ 200 Mbps	640 Mbps
PLATFORM	SPIN-STABILISED	3-AXIS STABILISED/ SUN-SYNCHRONOUS	AGILE	3-AXIS STABILISED/ SUN-SYNCHRONOUS
YEAR	**1979**	**1988-2012**	2001-2012	**2012**

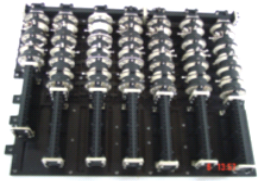
TRANSPONDERS: PRESENT COMMUNICATION SATELLITES



XPDR	55 deg E		74 deg E		83 deg E		93.5 deg E		
	INSAT-3E	GSAT-8	INSAT-3C	INSAT-4CR	INSAT-3B	INSAT-4A	INSAT-3A	INSAT-4B	GSAT-12
MSS	-	-	1 SxC 1 CxS	-	1 SxC 1 CxS	-	-	-	-
Ext. C	12	-	6	-	12	-	6	-	12
Nor. C	24	-	24	-	-	12	12	12	-
Ku	-	24	-	12	3	12	6	12	-
Others	-	-	2 BSS (C x S)	-	-	-	-	-	-

Communication Payload Systems

Filters & Multiplexers :



Ku-band OMUX : INSAT- 4C

Output Multiplexers -

INVAR Waveguide Type

Programs : **INSAT-2A, 2B, 2C, 2D, 2E, 3A, 3B, 3C**
INSAT- 4A, 4B, 4C (S, C & Ku-band)

Dielectric Loaded Type

Programs : **GSAT- 5 (C- band QM under progress)**

C-band High Power OMUX : INSAT- 3A

Typical Performance:

Insertion Loss	: 0.5 dB
Bandpass Flatness	: 1.0 dB
Group Delay	: 72 nS
Rejection	
At Cf ± 25 MHz	: 27 dB
At Cf ± 40 MHz	: 40 dB

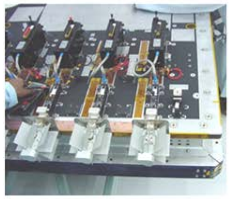
TWTA :

Conduction Cooled : INSAT- 2C, 2D, 2E, 3A, 3B, 3C, GSAT- 2
(S, C & Ku-band, 63 & 70 W)

Radiation Cooled : GSAT-3, INSAT- 4A, 4B, 4C
Ku-band, 140 W Linearized

C-band LTWTA Assembly : INSAT-4A

SSPA : INSAT-2A, 2B, 2C, 2D, 2E, 3A, 3B, 3C, 3E
GSAT-3, INSAT- 4A, 4B, 4C (C& Ku band 0.25 to 15 W)



Ku-band Radiation Cooled LTWTA : INSAT-4A

Typical LTWTA Performance:

P_{sat}	: 140 W
Efficiency	: 59 %
3rd order IMP at 6 dB IBO	: < - 18 dBc

Antenna System :

Single Shell Shaped & Un-shaped Reflector (Fixed & Deployable, S,C & Ku-band):

Programs :INSAT-2A, 2B, 2C, 2D, 2E, 3A, 3B, 3C, 3E

Reflector Size :From 0.9m to 2m

Dual Gridded Shaped Reflector (Deployable, C & Ku-band):

Programs : INSAT-4A,4B

Reflector Size : 2.0 & 2.2m

Multi-Beam (Ku & Ka-band) :

Program : GSAT-3 (In orbit), GSAT-4 (Y2008 launch)

Reflector Size :1.2m, 5 Beams Ku-band
Sectored, 8 Beams Ka-band

Ku-band High Power Output Section
INSAT-4A Payload Panel

Typical Performance in Ku-band:

Gain (EOC, India Coverage)	: 32.5 dBi
Cross Pol. Isolation	: < - 33 dB

Dual Gridded Shaped Reflector Antenna System
INSAT-4A : Ku-band Payload

Sectored Reflector Multi-beam Antenna System
GSAT- 4 : Ka-band Payload

INVAR Waveguide Type : INSAT-2A, 2B, 2C, 2D, 2E, 3A, 3B, 3C,
INSAT- 4A, 4B, 4C (S, C & Ku-band)

Dielectric Loaded Type : GSAT- 3, INSAT- 4A, 4B (C-band), GSAT-8

Typical Performance:

Bandpass Flatness	: 0.6 dB
Group Delay	: 38 nS
Rejection	
At Cf ± 25 MHz	: 30 dB
At Cf ± 40 MHz	: 45 dB

Filters & Multiplexers

C-band DR IMUX: INSAT-4A

Ku-band IMUX: INSAT-4C

Hybrid MIC: INSAT-2A, 2B, 2C, 2D, 2E, 3A, 3B, 3C, S, C & Ku-band

MMIC : GSAT- 5 (C-band under Qualification)
GSAT-7 (Ku-band QM under progress)

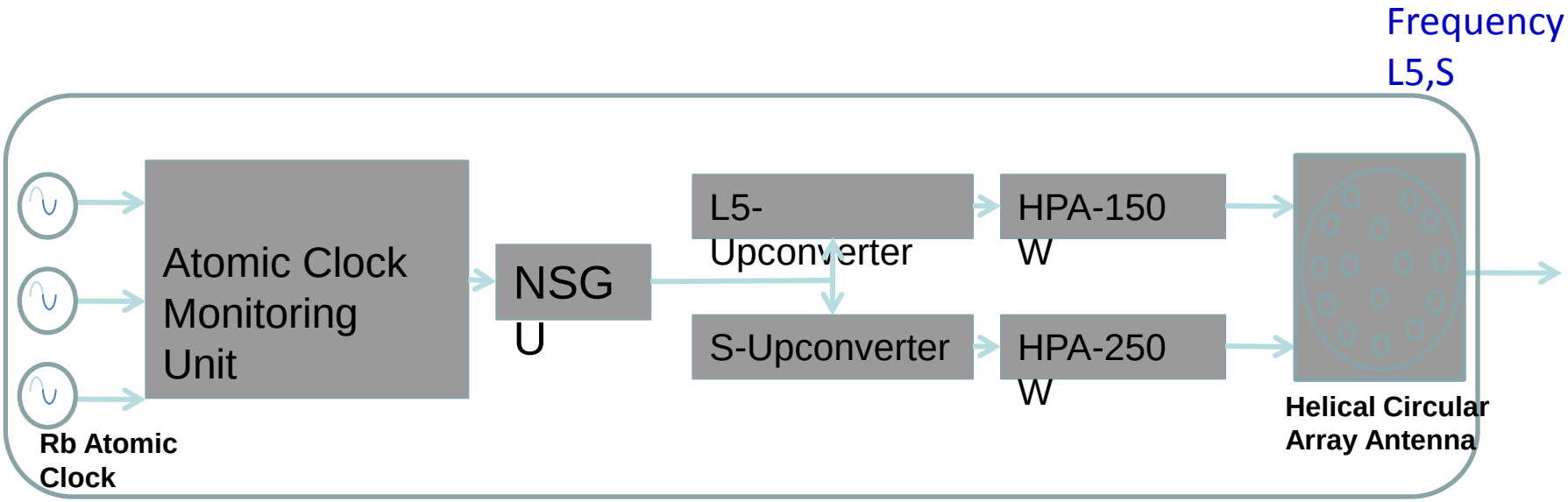
C-band Receiver: INSAT-4A

Typical Performance:

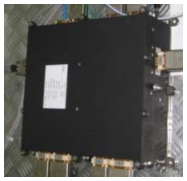
Frequency Translation	: 2225 MHz
Noise Figure	: 1.4 dB
Gain	: 52 dB
Spurious	: < -60 dBc

C-band MMIC Module

Navigation payload-IRNSS



Rb- Clocks



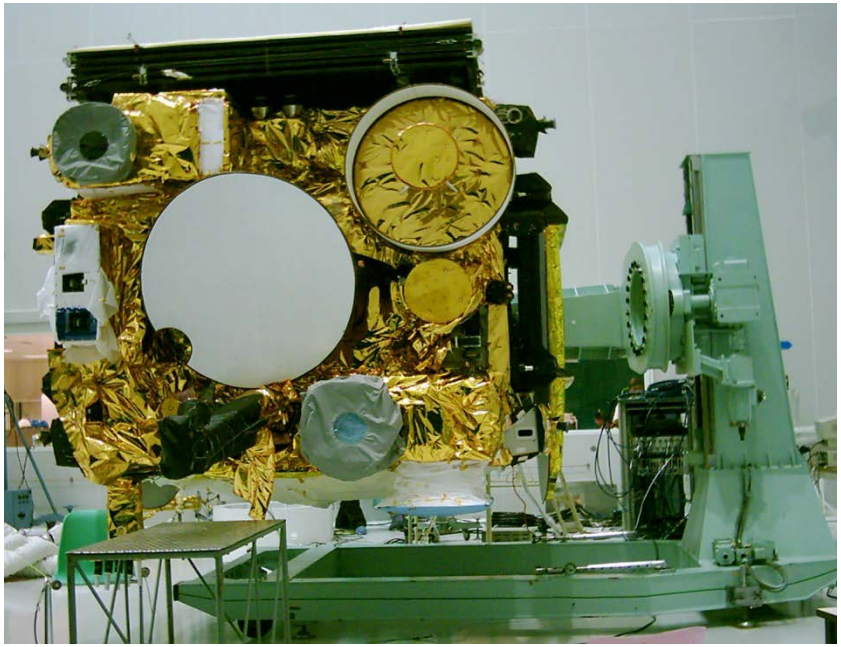
ACMU

NSGU

Mod-Upconverter

Dual Band Helical Array Antenna

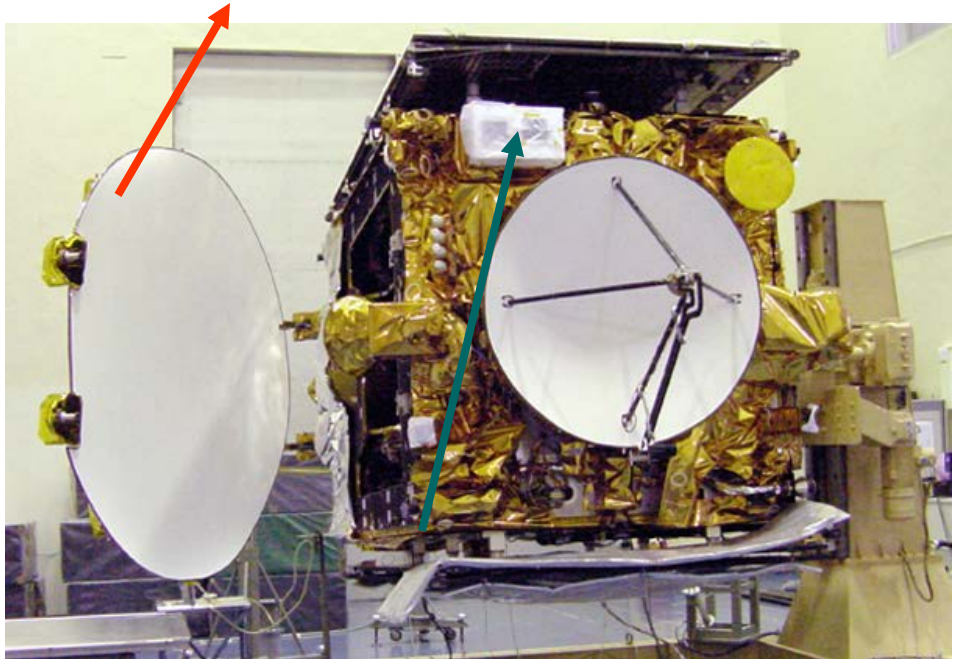
Onboard Reflector Antennas



EV deployable & fixed Antennas

INSAT3

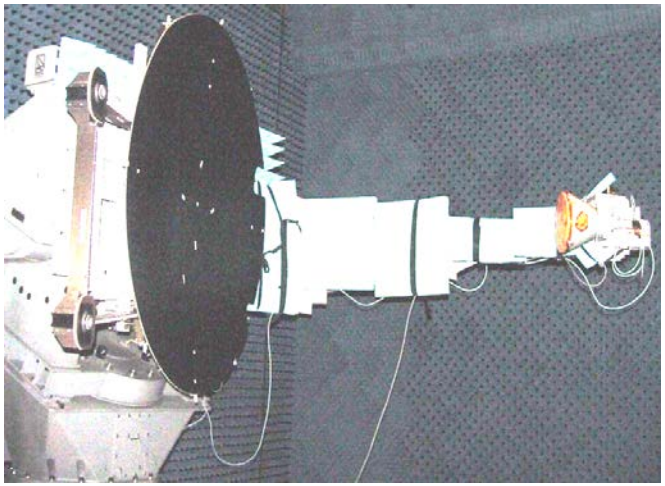
2m Deployable Antenna on EV Top



EV Mounted Prime Focal Antenna

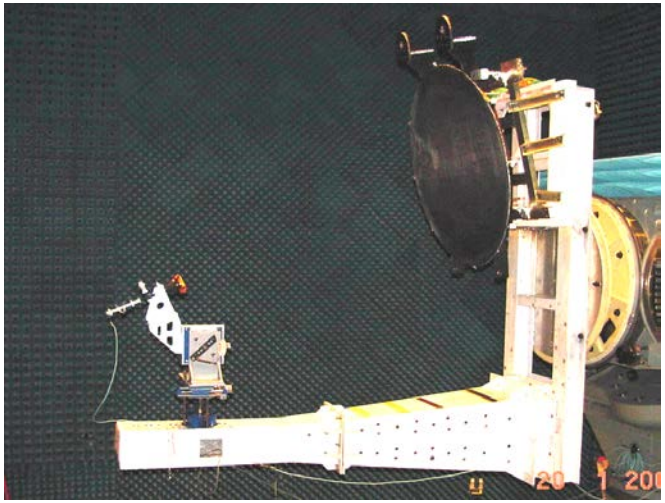
GSAT3

On Board C/Ku Band Shaped Antennas

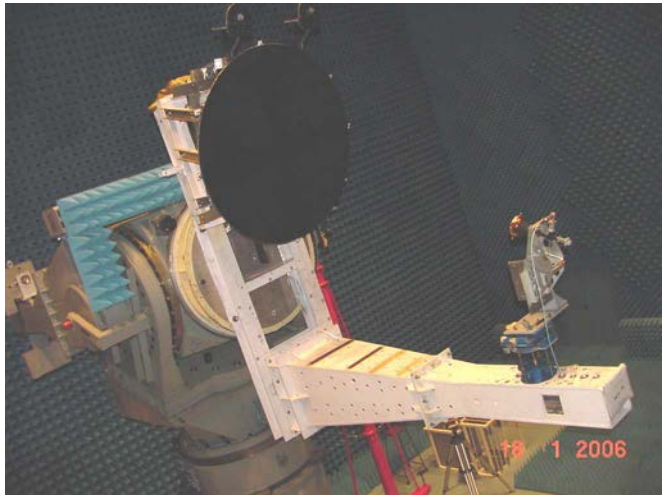


INSAT-3E Antenna System

INSAT-3C Antenna System



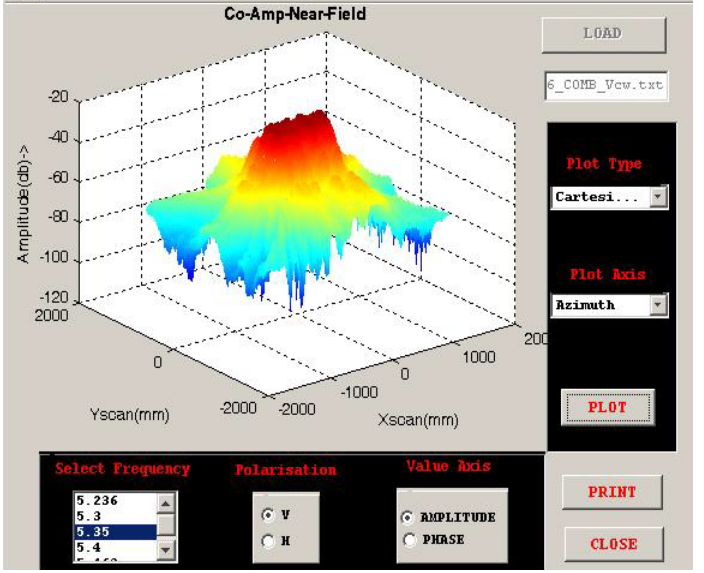
INSAT-4C Antenna System



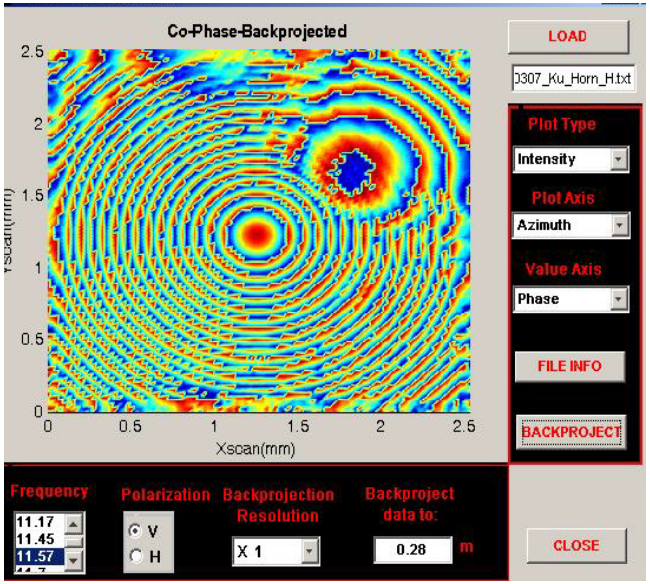
INSAT-4C Antenna System

ANTENNA MESUREMENT FACILITY

COMPACT ANTENNA TEST RANGE



Near-Field diagnosis Module



- Remote sensing optical payloads
- Microwave payloads
- Communication and navigation payloads
- LEO- GEO-Lunar and planetary orbits
- Atomic clock developments

Thank You!

A.S. Kiran Kumar
Director
Space Applications Centre